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MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY

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MAY, 1928

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WORLD WEATHER[1]

By Sir GILBERT WALKER

The data recognized as necessary for the forecasting of weather come from a region that is ever widening. Before telegraphic charts were prepared the local observatory had to suffice; but the daily maps now used in predicting the weather of a single country of Europe may cover several thousand miles from west to east. Further, the desirability of warnings of the famines that have devastated semitropical and tropical countries has led to thinking in terms of seasons rather than days, and it soon became clear that seasonal variations over much of the earth are related to a surprising extent.

The first fact emerged in 1878 when Hoffmeyer pointed out the association between pressure in the North Atlantic and weather in Europe; and he was shortly followed by Blanford in India and by a group of continental meteorologists, including Teisserenc de Bort, Hann, Meinardus, and Pettersson. The far-reaching character of the subject was first visualized by Hildebrandsson, who in 1897 published the pressure data for 10 years of 68 stations scattered over the world, and directed attention to certain relations between them as indicated by plotted curves. But in this and in his later papers, the graphic methods used, and the shortness of the series of data available, generally prevented him from reaching final conclusions. In 1902 the Lockyers confirmed his discovery of the "seesaw" of pressure in the Argentine and in India or Australia, and, still using purely graphical methods, they made it the basis of a classification of pressures over the world according as they oscillated with India or with Cordoba.

Since then, work on the Continent has been chiefly occupied with conditions in northern latitudes, and the more general problem has been mainly studied in connection with Indian monsoon forecasting. For this purpose it was necessary to have quantitative information as to relationships, not merely visual impressions from plotted curves, and to work with seasonal, not annual, values. Also there was no hope of unraveling the tangled threads of causes and effects unless help was got by finding cases in which the conditions in one place were related with those in another in a subsequent season. Statistical methods were therefore indicated, and these efforts have culminated in the production of tables of relationships between conditions of pressure, temperature, rain, or river flood at 32 centers scattered over the world. For each of these the correlation coefficient has been worked out for each quarter with those of contemporary quarters of the other stations, and also with those of one quarter before and after, and with those of two quarters before and after.

The total number of coefficients worked out is considerable, but simplification of the process has reduced the time spent on each to one or two minutes; also, by confining attention to those figures which are larger than the biggest that chance can be expected to produce, the number of significant figures is reduced to 396, and these fall very consistently into the scheme of oscillations indicated below.

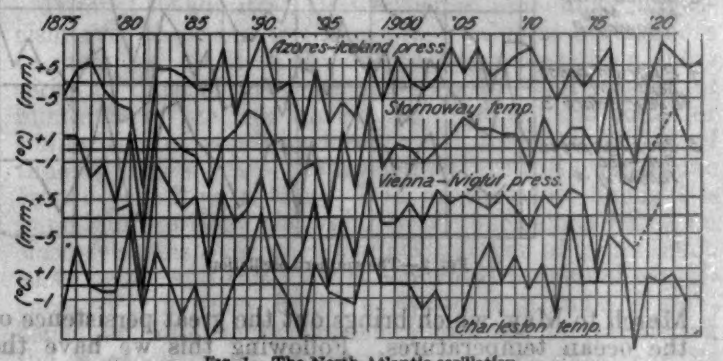


FIG. 1.—The North Atlantic oscillation

The main conclusion reached is that there are three big swayings or surgings:

(*a*) The North Atlantic oscillation of pressure between the Azores or Vienna on one hand and Iceland or Greenland on the other;

(*b*) The North Pacific oscillation between the high-pressure belt and the winter depression near the Aleutian Islands; and

(*c*) The southern oscillation mainly between the South Pacific and the land areas round the Indian Ocean.

Regarding (*a*), it is well established that a strengthening of the pressure gradients and of the ocean winds (indicated in Figure 1 by the pressure differences Azores—Iceland and Vienna—Greenland) is associated with a strengthening of the Gulf Stream and higher temperatures in northern Europe (e. g. Stornoway in fig. 1) and along the east coast of the United States (e. g. Charleston). The diagram shows the variations of these quantities in successive Januaries from 1875 for nearly 50 years, and the relationships are closer than is generally realized, the correlation coefficient (or degree of association) between the second and third curves being 0.88. Increased circulation goes also with higher temperature in Siberia and Java and less monsoon rainfall in India.

[1] This article contains the substance of a recent presidential address to the Royal Meteorological Society.

The editor is glad to reprint from *Nature*, London, May 5, 1928, the address of Sir Gilbert Walker in full on the subject of world weather in its relation to seasonal forecasting, and to add for the benefit of American readers that as Director General of Observatories of the Indian Meteorological Bureau, 1904–1924, it was Sir Gilbert's privilege to improve and place on a substantial basis the method of monsoon forecasting originated by his predecessors.

His researches and contributions on that subject easily make him the outstanding pioneer in seasonal forecasting.—*A. J. H.*

The North Pacific oscillation is rather like that of the North Atlantic, strengthening of the winter pressure differences and winds being associated with higher winter temperatures in central and western Canada, and increased rain in the North Pacific Coast States.

The southern oscillation is more far-reaching than the two oscillations just described, and as the effect of an abnormal season is propagated slowly, it may not appear at the other side of the earth until after an interval of six months or more. In illustration we may see in Figure 2 in the topmost curve the variations of the Nile floods of July to October in successive years from 1889 to 1925; they are, however, reversed, so that a dip below the normal line like that of 1916 means a high Nile. The next curve shows the variations of temperature at Samoa in the following summer, December to February, and the correspondence is obvious, the coefficient between the departures being 0.72. The third curve is that of Samoa temperature during the succeeding autumn,

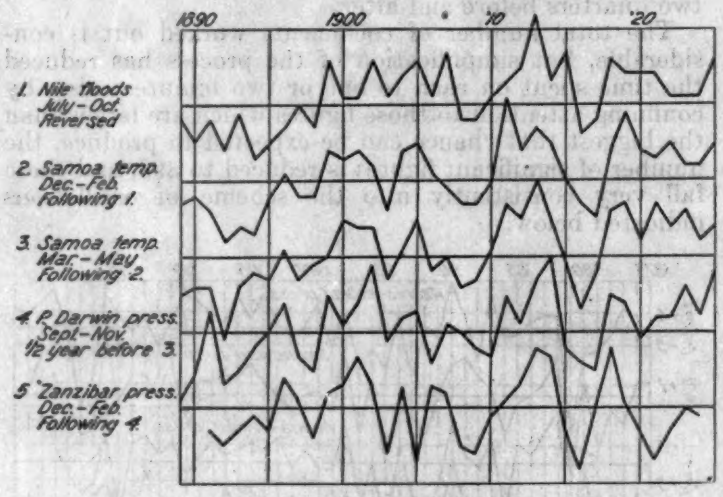

1890
1900
'10
'20
1. Nile floods July-Oct. Reversed
2. Samoa temp. Dec.-Feb. Following 1.
3. Samoa temp. Mar.-May Following 2.
4. P. Darwin press. Sept.-Nov. ½ year before 3.
5. Zanzibar press. Dec.-Feb. Following 4.

FIG. 2.—The southern oscillation

March to May, which brings out the great persistence of the ocean temperatures. Following this we have the pressure at Port Darwin in North Australia for September to November, six months before the third curve, yet with so close a correspondence that the coefficient between them is 0.80. Lastly, we have the pressure at Zanzibar of December to February three months later, and so three months after the third curve, with which its coefficient is 0.72.

The general character of the southern oscillation may be inferred from the statement that in the season June to August the first group of stations, i. e., that oscillating with pressure in the Pacific, is most clearly represented by pressure at Honolulu, Samoa, the Argentine, and Chile by India monsoon rainfall and by the Nile floods; and the second group, tending to have departures of the sign opposite to those of the first, is represented by Port Darwin pressure, and by temperature at Batavia and Samoa. During the season December to February the most representative stations are materially different. In the first group there are only Samoa pressure and rainfall at Java; and in the second, pressure at Honolulu, Zanzibar, North-West India, Port Darwin, and the cape, with the temperatures of central North America, Batavia, and Samoa.

The first question that arises is that of the mechanism that binds together the southern oscillation; we have seen that the North Atlantic and North Pacific oscillations implied variations in the strength of the air circulation in those areas, and there is a presumption that a similar interpretation is applicable here. Now where there are areas of low pressure and areas of high pressure in the same latitude, the former are in general relatively warm and the latter relatively cool; so that in winter, seas have low pressure and in summer, high; and for land the opposite obtains. Thus the low pressures of Iceland and the Aleutian Islands are much more developed in winter than in summer, and the high-pressure belts in the Atlantic and Pacific in summer than in winter. Accordingly, in the southern oscillation the first group consists of those areas the pressure of which will increase with increased temperature contrasts or increased circulation; thus, in the Pacific, Honolulu is in the first group in summer when the high-pressure area is more marked, and in the second group in winter when the reverse obtains; similarly, the Argentine and Chile as land areas are only in the high-pressure group in winter. Also Samoa as a high-pressure center at times of increased circulation is much more marked in summer than in winter; and the cape is only in the second group in its summer when pressure is relatively low.

This explanation is not complete, however, for northern Australia is almost as strong in the second group in its winter as in its summer. Further, at times of increased circulation, when we should expect solar radiations to be stronger, temperatures are markedly lower except in higher latitudes. But here we are reminded of the old paradox, that at times of sun-spot maxima, when there is a definite though small general increase of rainfall owing presumably to increased circulation, temperature is decidedly lower in the Tropics and generally lower in the middle latitudes; and, going further, if we compare the relationships of sun spots with pressure, temperature, and rainfall, we find a remarkably close resemblance with those of the southern oscillation, extending in many cases into the detail. Thus if we consider our description of the southern oscillation in terms of representative centers, there were, in the season June to August, five centers in the first group and three in the second, while from December to February the numbers were two and eight; and without an exception we find the variations of centers of the first group associated positively with those of sun spots and those of the second group negatively, even when the members of the group change between summer and winter.

This correspondence would be explained if the southern oscillation were an effect of sun spots; but this hypothesis is untenable as the relationships between factors in the southern oscillation are much closer than those between the factors and sun spots. It seems too speculative to postulate some solar influence which should closely control terrestrial conditions and yet have but a small influence on the sun-spot numbers. So we are led to the view that the southern oscillation merely expresses a natural oscillation or system of surges in the general circulation, and that, for example, the fall of temperature in the Tropics is, on physical grounds, associated with an accentuation of low pressure in the Indian Ocean. If this is granted we suppose that an increase in the number of sun spots or of solar radiation will increase slightly the general circulation and so bring about the observed relationships with sun-spot numbers.

The belief held by Hildebrandsson in 1910 was that, in the tropical and temperate regions, cicumstances were too regular to afford an explanation, and it must lie in the ice conditions of the polar seas; he believed also that

in the Southern Hemisphere types of season were propagated eastward like waves, the character of the pressure at the cape during its summer appearing at Mauritius in the next winter, in Java and Australia the succeeding summer, and finally in South America six months later or 18 months after its original appearance at the cape. This generalization was founded on inadequate materials, and the feature which stood out most prominently in the first set of relations worked out in India was that while winter pressures in the Argentine and Chile were not controlled by any center in the southern oscillation six months before, they controlled conditions six months later around the Indian Ocean, appearing as a reversed pressure wave which took six months to reach the cape. It seemed therefore as if South America was the origin of the variations.

At first it appeared that a modification of Hildebrandsson's hypothesis would solve the problem. For, owing to the shape of the Antarctic continent, it would seem inevitable that the ice which flows in a westerly direction along the coast would be thrown off northwards into the Drake Strait by the projection of Graham Land, so that it would then flow northeastward and eastward in the currents of the "roaring forties." The few data forthcoming from that neighborhood indicated that a winter of low pressure in Chile was a winter of much ice at the South Orkneys, and as this would take some months to produce an area of chilled ocean and therefore of high pressure at the cape, it seemed as if we might hope to understand how a period of low winter pressure in South America could produce a period of high summer pressure at the cape. But subsequent examination showed that although low winter temperature at the South Orkneys produced low temperature at the cape a year later, the coefficient between the two temperatures being +0.56, the effect six months later was small; and, apart from this, the explanation would break down because the effect of cape temperature on cape pressure proves on calculation to be negligible.

Unfortunately, it is easier to reject this hypothesis than to replace it. If we count in the tables the number of significant relationships, we find that pressure at Port Darwin has no less than 76 with other places, of which 32 are with subsequent seasons; next in importance come temperatures at Batavia and Samoa, each with about 60 relationships, of which only 13 are with subsequent seasons; and then come the pressures of Northwest India and Samoa with smaller numbers. So pressure in the neighborhood of Port Darwin seems to exercise more control over other regions than any other world factor, and its influence seems to be increased by Batavia temperature, which varies in close sympathy. Temperature at Samoa, the oscillations of which closely resemble those of Batavia temperature, is an equally important world center, but belongs to the second group, while Samoa pressure belongs to the first group and has not more than half its influence. On the whole, then, although certain pressures appear to come earlier than any temperatures in the sequence of cause and effect, it is clear that ocean temperatures play a most important part in world weather. Their effectiveness may be due in part to their extreme persistence, so that successive seasons produce cumulative instead of antagonistic results.

Although it may be some time before we learn the processes by which nature effects these enormous oscillations, and the relationships found must in general be regarded as empirical, there is no reason why they should not be utilized when possible for administrative or commercial purposes such as seasonal forecasting. Thus methods of predicting the general character of the winter and spring temperatures of a large part of northern Europe have been known for 20 years, and much additional knowledge has been won in recent researches by Brooks, Exner, Wiese, and others. The facts of the southern oscillation have been systematically utilized in predicting the rice crops of Japan, and the Java rainfall; and the recent tables have been shown by Bliss to have an immediate application to the Nile, the final relationship for forecasting being 0.72. The latest purpose to which they have been directed is in connection with Ceara, a State in northeast Brazil liable to terrible droughts, and, as rainfall there belongs to the second group in the southern oscillation, a formula with a coefficient of 0.82 follows at once, the effect being shown in Figure 3.

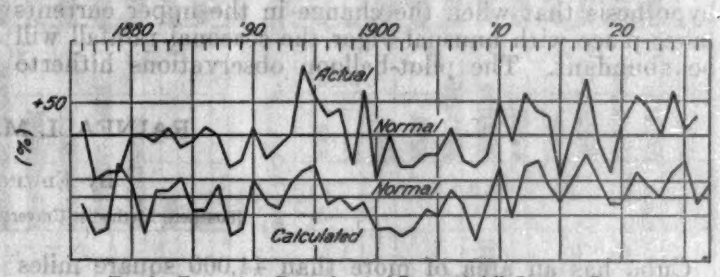


FIG. 3.—Forecast on December 1 of Ceara rainfall, January–June

It must be admitted that a certain amount of skepticism over these matters is of great value as an antidote to rashness; for it is obvious that if we examine short series of data of pressure, temperature, and rainfall of hundreds of stations chosen at random, and look for similarities of conditions separated by all intervals of time up to five years, the laws of chance will provide one or two promising results. But, on the other hand, it is impossible to deny the validity of conclusions based on close relations over an adequate number of years, such as 40 or 50, and this view is confirmed by actual experience. For in 1908, in my early years in India, I published an admittedly imperfect formula for predicting the monsoon based on about 34 years of data; and its reliability can be definitely estimated by comparing the indications that would have been given by it if employed during the past 19 years with the actual rainfall. Now the coefficient expressing the closeness of fit between the results of the formula and past data in 1908 was 0.58, and I should have been satisfied under the conditions if the indications of the past 19 years had a closeness of fit of 0.48 instead of 0.58; actually, however, as will be seen from Figure 4, the foundations of the relationship have proved sound and the coefficient has worked out as 0.56; so it may be claimed that our present improved formulae based on 50 or 55 years instead of 35 years are worthy of confidence if used with due caution. It is in my view essential that forecasts should only be issued when the indications are well marked, and if during the past 19 years a prediction had only been made in the 11 years when an excess or deficit of 1 inch or more had been indicated, the character of the season's rainfall, expressed merely as "in excess" or "in defect," would have been correctly given nine times (Fig. 4).

Since 1908 many new relationships have been ascertained, and the present formulas for north west India and for the peninsula have coefficients of 0.76 instead of 0.58. Also, there is no reason whatever for thinking that finality has been reached; for with the seasonal

changes in India are associated very big changes in the strength of the upper currents; and it is an obvious hypothesis that when the change in the upper currents takes place with unusual vigor the seasonal rainfall will be abundant. The pilot-balloon observations hitherto made strongly support this hypothesis, and what appears to hold in India very probably holds over a far wider region. Moreover, the idea that upper-air conditions are vital to the study of world weather derives support from the table of relationships with the Nile. The significant relationships with other stations for its single season number 31, while the greatest number for a single season at any other center is 24; and as the corresponding number for pressure at Cairo is only 8, it seems likely that this effect of the Abyssinian rainfall is brought about by the agency of the upper air, not by surface conditions. Similarly, the monsoon rainfall of India has eight significant relationships elsewhere, but June to August pressure in northwest India only once.

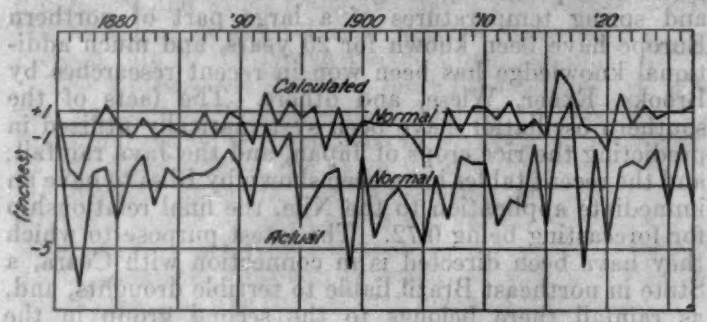


FIG. 4.—Forecast on June 1 of Indian monsoon, June-September. (1908 Formula, R=0.58)

It is to be hoped, therefore, that the tables of the *Réseau Mondial*, to which statistical workers have been enormously indebted in the past, will in future contain monthly means of air motion at fixed heights above such observatories as can provide the data.

RAINFALL MAPS OF CUBA

By EDWIN J. FOSCUE

[Southern Methodist University, Dallas, Tex., May 24, 1928]

Cuba has an area of more than 44,000 square miles and is approximately the size of Pennsylvania. In spite of the relatively slight relief there are pronounced differences in the total rainfall of the various parts of the island, due largely to its embayed coast and to the seasonal shift of prevailing winds.

Accurate and detailed records of the rainfall on the island are few, and for the surface involved, the 19 long-record stations used in the series of maps presented with this paper are by no means sufficient to make a detailed study of the rainfall of the island. However, as there exist no detailed maps of Cuba showing the annual and monthly distribution of precipitation,[1] the author feels that a graphic presentation of the available data should be of interest to students of tropical geography. Most of the data for these maps were obtained from the excellent publication by Dr. Oliver L. Fassig, on "Rainfall and Temperature of Cuba."[2] Rainfall data in this bulletin are given for 19 stations on the island with records varying between 14 and 25 years, with an average of about 20 years. Since the rainfall in the Tropics is so variable from year to year, it seemed desirable to get as long a record as possible for each station, so as to increase the accuracy of the maps. For uniformity the short-record stations were adjusted on the long-record stations so that the resultant was a 25-year average for each of the 19 stations shown on the identification map

FIG. 1

[1] The most complete general maps on rainfall and cloudiness in the West Indies are to be found in "Bewolkungs-, Niederschlags- und Gewitterverhältnisse der westindischen Gewässer un der angrenzenden Landmassen," by Dr. W. Kloster. (Aus dem Archiv der Deutschen Seewarte, Vol. 40, No. 1, pp. 3-67.)

[2] Fassig, Oliver L: Rainfall and Temperature of Cuba, Bull. No. 1, of the Tropical Plant Research Foundation.

(fig. 1). The formula used in computing this adjusted average is given below.[3]

After the adjusted figures of monthly and annual rainfall, as shown in the accompanying table, were calculated for the 19 stations, a series of monthly rainfall charts were made to show the rainfall types on the island. The more significant rainfall types are shown in the charts for Habana, Union de Reyes, Preston, and Santa Barbara. Habana has the lowest record of any station on the island, with a total only 43 inches, while the near-by station of Union de Reyes has the highest, with more than 72 inches. Preston, in northeastern Cuba, has a pronounced winter maximum, while Santa Barbara, on the Isle of Pines, has a double summer maximum. (Fig. 2.)

FIG. 2

On the map of annual rainfall, isohyets of 5 inches were used, with a shading for every 10 inches. This map (Fig. 3) shows in a general way the concentration of rain in the southwestern part of the island, and the relatively light rainfall throughout the entire eastern half of the island. The eastern and western halves of the island are not exactly comparable, however, as all of the stations in the eastern part are at, or near, sea level, and do not tell the conditions in the mountains back of Santiago, which rise in places above 5,000 feet.[4] The map shows, however, that the region of the summer maxima has by far the greatest accumulated rainfall for the year.

MONTHLY RAINFALL

The maps showing the monthly distribution of rainfall for the island of Cuba (fig. 4) were constructed from the adjusted monthly means shown in Table 1. The same difficulty was experienced here as with the annual map. Due to a lack of stations in the mountainous southeastern part of the island, it was quite difficult to make a fair

[3] Formula:

$$\frac{\text{Total rainfall for short record station}}{\text{Total rainfall for long record station (same years as short record station)}} \times \text{Total rainfall for long record station (25 years)}.$$

x=adjusted total for short record station for 25 years.

$\frac{x}{25}$=adjusted annual rainfall for the short stations.

The monthly means were computed proportionately from the annual mean.

[4] See Reed, W. W.: "Climatological Data for the West Indian Islands," in MONTHLY WEATHER REVIEW, April, 1926, 54: 140-141.

representation of the probable rainfall in that section, and in consequence the writer had to be satisfied with mere suggestions now and then, similar to that on the annual map. The maps show isohyetal lines for every inch of rainfall, and different shades for each 2 inches. In addition to this the prevailing wind directions are placed in each monthly map to show the influence of these winds upon the distribution of precipitation.[1]

The months of January, February, March, and April, and of November and December, have the lightest rainfall, while the hot months of June, July, August, and September have the greatest rainfall. Two pronounced maxima occur over most of the island in June and September, the rainfall during July and August being lighter than either of these. May and October represent transitional months between the heavy rainfall of summer and the lighter rainfall of April and November. The June maximum over most of the island is due to the numerous convectional showers brought about by the vertical rays of the sun passing over Cuba twice during that month, and to the heavy rainfall along the south coast of the western part of the island facing the prevailing on-shore winds from the southeast. The September maximum is largely the result of tropical hurricanes that are most numerous in the West Indies during that month. The path of greatest frequency of these cyclonic storms lies through the western part of the island.

Considering the areal distribution of precipitation on the monthly maps, it appears that the prevailing winds have a marked influence. During the winter months the northeast trade-winds prevail and the eastern half of the north coast is exposed. This brings the heaviest rainfall in the northeastern part of the island, centering around the town of Preston, with the rain shadow covering most of the remainder of the island. The area included in this winter maximum is small. By the beginning of May the prevailing winds turn through east to southeast, and bring an on-shore wind to the southern side of the island. This gives the stations on the southern and southwestern parts of the island the heaviest rainfall during the summer, and places the northeastern coast in the rain shadow, with the minimum precipitation at Preston, the same place that had the maximum rainfall during the winter. It should be kept in mind, however, that there are no stations in the mountainous southeastern part of the island. That section, with its high mountains, undoubtedly has a much heavier rainfall on its windward slope than can be shown on the maps. In November the winds change back to their former direction, and the northeast trades prevail from then until the end of April.

Since the relief of Cuba is slight, with the exception of the mountains back of Santiago, the seasonal influence of prevailing winds, and the embayed coast, appear to be the most important factors in the areal distribution of rainfall.

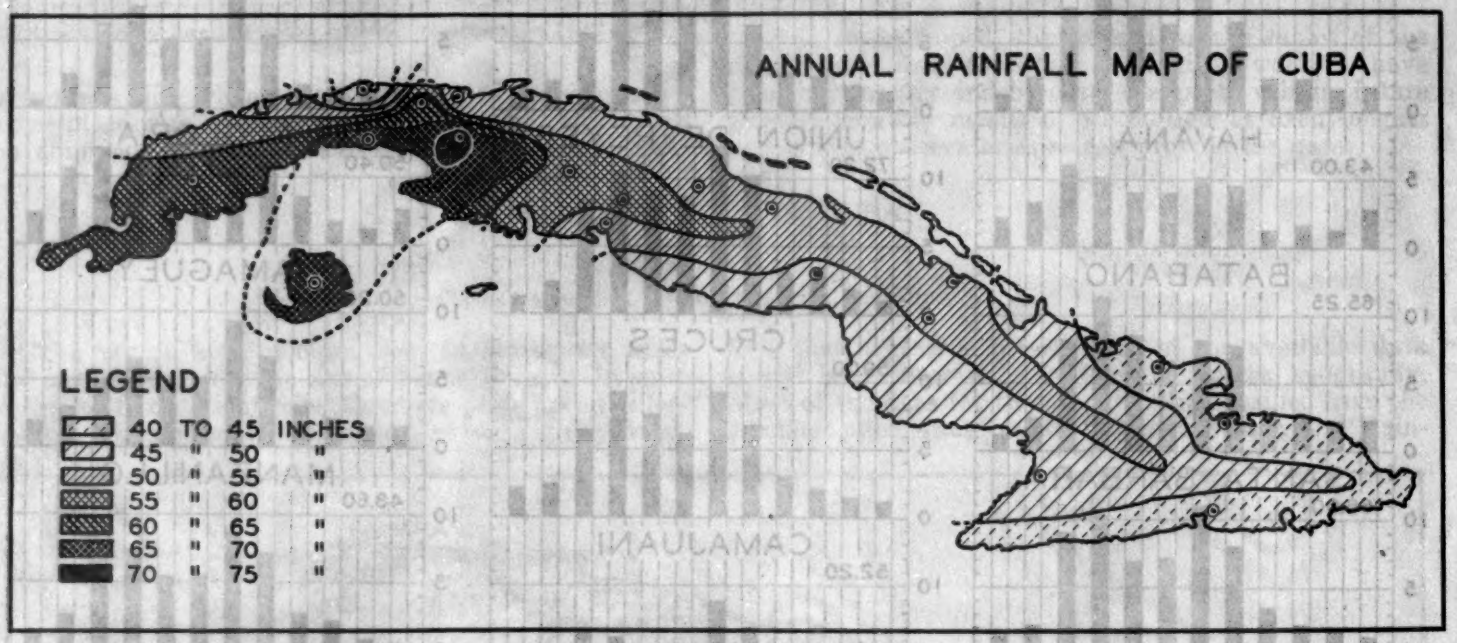


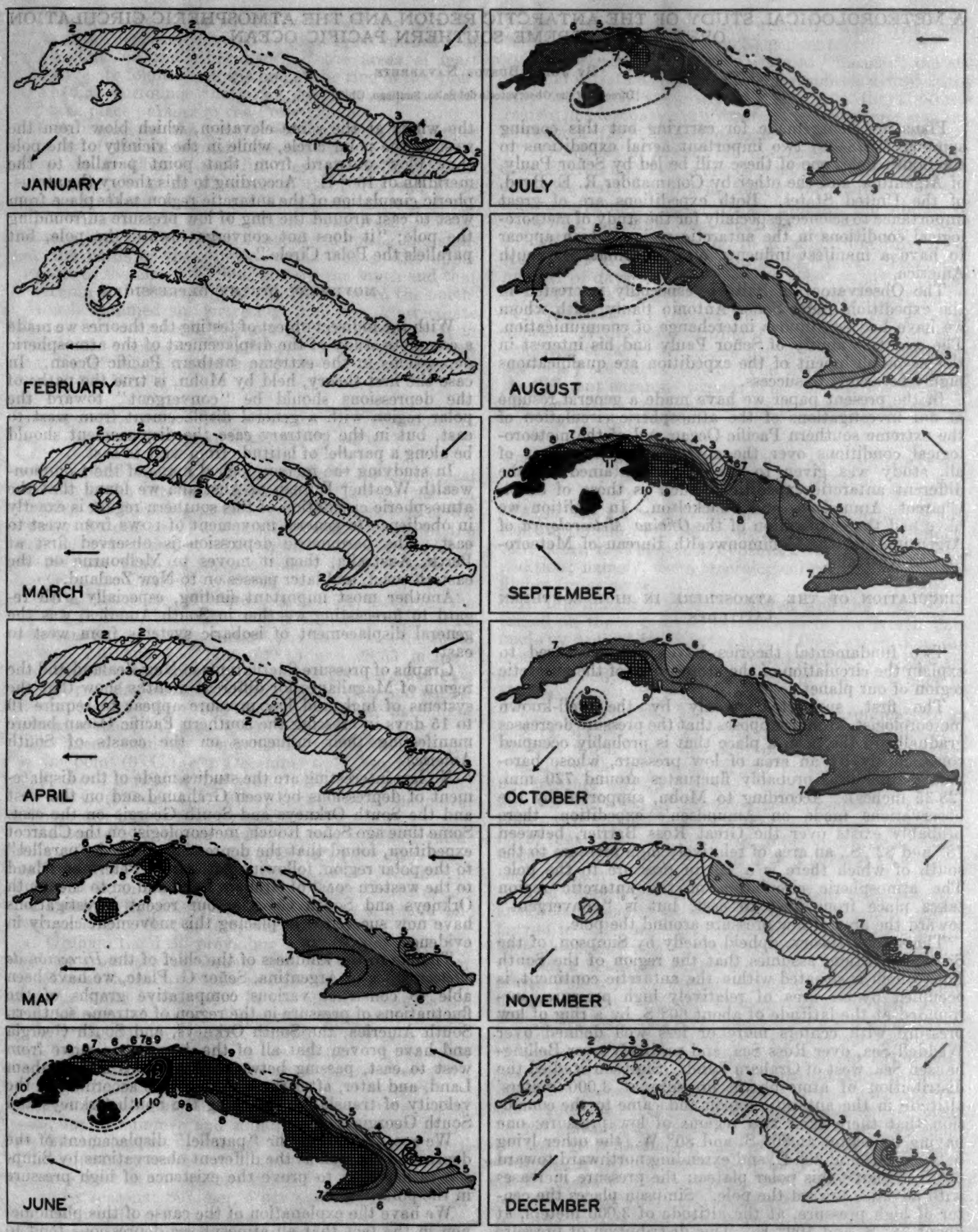
FIG. 3

[1] From Monthly *Sailing Charts* of the North Atlantic Ocean. United States Coast and Geodetic Survey, Department of Commerce, Washington, 1923.

TABLE 1.—*Adjusted monthly and annual rainfall of Cuba (19 stations)*

No.	Station	Jan.	Feb.	Mar.	Apr.	May	June
1	Pinar del Rio	1.82	1.74	2.48	2.62	6.97	10.29
2	Havana	2.98	1.33	1.78	1.58	4.71	5.26
3	Batabanó	2.42	2.07	2.53	2.69	7.92	8.13
4	Santa Barbara	1.40	2.01	2.24	3.06	8.08	11.05
5	Aguacate	2.18	1.85	2.46	2.63	7.75	9.88
6	Matanzas	2.52	1.36	2.32	2.37	5.94	9.32
7	Banaguises	1.17	1.79	2.48	2.84	6.45	9.36
8	Union de Reyes	0.99	1.88	3.15	3.02	10.20	12.27
9	Cruces	1.40	1.68	2.16	3.16	6.90	9.30
10	Camajuani	1.93	1.05	1.44	2.73	6.02	8.80
11	Yaguajay	1.95	1.40	2.08	2.93	5.70	8.40
12	Cienfuegos	1.26	1.44	1.87	2.29	6.44	7.63
13	Ciego	1.03	1.19	1.26	1.96	5.44	9.41
14	La Gloria	2.61	1.29	1.62	3.50	5.68	5.62
15	Camaguey	1.49	1.36	2.20	3.28	6.90	9.40
16	Manzanillo	0.57	0.80	2.05	2.84	7.14	8.70
17	Santa Lucia	2.85	1.40	1.38	2.00	5.80	3.58
18	Preston	4.03	2.21	1.25	2.88	4.65	2.36
19	Santiago	1.44	0.83	1.67	3.15	6.15	5.12

No.	Station	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
1	Pinar del Rio	6.61	7.01	10.65	7.74	2.46	1.39	61.78
2	Havana	4.33	4.27	5.18	6.21	3.20	2.17	43.60
3	Batabonó	6.41	8.95	11.77	8.46	2.62	1.28	65.25
4	Santa Barbara	7.20	7.15	10.40	9.25	2.14	1.55	66.00
5	Aguacate	7.88	6.37	8.84	6.05	2.84	2.12	60.85
6	Matanzas	4.50	5.40	5.75	6.10	2.61	3.32	52.00
7	Banaguises	7.02	7.30	9.02	5.32	2.28	1.58	56.48
8	Union de Reyes	8.55	9.05	10.55	8.38	2.24	1.43	72.20
9	Cruces	6.20	7.90	9.44	6.40	2.42	2.15	59.00
10	Camajuani	4.95	5.20	2.05	6.75	4.61	2.68	52.20
11	Yaguajay	4.36	5.78	7.55	6.50	4.99	2.08	53.88
12	Cienfuegos	6.18	6.48	8.04	7.32	2.14	1.25	52.34
13	Ciego	5.28	5.21	7.87	6.70	2.58	0.56	47.16
14	La Gloria	3.60	3.40	6.18	7.08	5.57	2.30	50.40
15	Camaguey	5.02	5.00	6.52	4.90	2.82	1.86	50.20
16	Manzanillo	5.40	5.52	7.72	6.50	2.43	1.24	48.60
17	Santa Lucia	1.71	2.62	4.28	6.50	7.60	3.05	43.24
18	Preston	1.50	2.08	3.88	6.42	8.21	5.31	44.76
19	Santiago	2.14	3.41	6.25	7.05	3.44	1.00	41.40



MONTHLY RAINFALL OF CUBA

FIG. 4

A METEOROLOGICAL STUDY OF THE ANTARCTIC REGION AND THE ATMOSPHERIC CIRCULATION OVER THE EXTREME SOUTHERN PACIFIC OCEAN

By JULIO BUSTOS NAVARRETE

[Director of the Observatorio del Salto, Santiago, Chile]

Plans are being made for carrying out this coming summer (1928–29) two important aerial expeditions to the South Pole; one of these will be led by Señor Pauly, of Argentina, and the other by Commander R. E. Byrd, of the United States. Both expeditions are of great importance to science, especially for the study of meteorological conditions in the antarctic region, which appear to have a manifest influence on the climate of South America.

The Observatory of Salto is especially interested in the expedition under Señor Antonio Pauly, with whom we have had continuous interchange of communication. The scientific ability of Señor Pauly and his interest in the accomplishment of the expedition are qualifications highly favorable to success.

In the present paper we have made a general résumé of our investigations of the atmospheric circulation of the extreme southern Pacific Ocean and of the meteorological conditions over the antarctic region. First of all, study was given to the results obtained by the different antarctic expeditions, such as those of Scott, Charcot, Amundsen, and Shackelton. In addition we have had the cooperation of the *Oficina Meteorolojica* of Argentina and the Commonwealth Bureau of Meteorology of Australia.

CIRCULATION OF THE ATMOSPHERE IN HIGH SOUTHERN LATITUDES

Two fundamental theories have been advanced to explain the circulation of the atmosphere of the antarctic region of our planet.

The first, supported mainly by the well-known meteorologist, Mohn, supposes that the pressure decreases gradually to the pole, a place that is probably occupied continuously by an area of low pressure, whose barometric minimum probably fluctuates around 720 mm. (28.35 inches). According to Mohn, supported by the observations made on Amundsen's expedition, there probably exists over the Great Ross Barrier, between 78° and 82° S., an area of relatively high pressure to the south of which there is a fall in pressure to the pole. The atmospheric circulation of the antarctic region takes place from west to east, but is "convergent" toward the area of low pressure around the pole.

The second theory, upheld chiefly by Simpson, of the Scott expedition, assumes that the region of the South Pole, which is situated within the antarctic continent, is occupied by an area of relatively high pressure, surrounded at the latitude of about 60° S. by a ring of low pressure with centers more or less well defined over Weddell Sea, over Ross Sea, and probably over Bellinghausen Sea, west of Graham Land. Simpson studied the distribution of atmospheric pressure at 3,000 meters' altitude in the antarctic region and came to the conclusion that there exist two regions of low pressure; one having its center at 80° S. and 80° W., the other lying between 20° and 60° E. and extending northward toward 62° S. Above this polar plateau the pressure increases with advance toward the pole. Simpson places the center of high pressure, at the altitude of 3,000 meters, at about 78° S. and 100° E. This distribution of pressure at 3,000 meters is in accord with the mean direction of the winds at the same elevation, which blow from the west at the polar circle, while in the vicinity of the pole they blow outward from that point parallel to the meridian of 160° E. According to this theory the atmospheric circulation of the antarctic region takes place from west to east around the ring of low pressure surrounding the pole; "it does not converge toward the pole, but parallels the Polar Circle."

MOVEMENT OF THE DEPRESSIONS

With the indirect object of testing the theories we made a complete study of the displacement of the atmospheric depressions in the extreme southern Pacific Ocean. In case the first theory, held by Mohn, is true the paths of the depressions should be "convergent" toward the polar region with a general displacement from west to east, but in the contrary case the displacement should be along a parallel of latitude from west to east.

In studying the meteorological maps of the Commonwealth Weather Bureau of Australia we found that the atmospheric circulation of this southern region is exactly in obedience to general movement of LOWS from west to east. The barometric depression is observed first at Perth, Australia, then it moves to Melbourne on the eastern coast, and later passes on to New Zealand.

Another most important finding, especially with regard to forecasting weather in South America, was the general displacement of isobaric systems from west to east.

Graphs of pressure fluctuations in New Zealand and the region of Magallanes for different months show that the systems of high and low pressure appear to require 10 to 15 days in crossing the southern Pacific Ocean before manifesting their influences on the coasts of South America.

No less interesting are the studies made of the displacement of depressions between Graham Land on the west and the South Orkneys and South Georgia on the east. Some time ago Señor Rouch, meteorologist on the Charcot expedition, found that the depressions moved "parallel" to the polar region, following paths from Peterman Island to the western coast of Graham Land and on to the South Orkneys and South Georgia; our recent investigations have now succeeded in placing this movement clearly in evidence.

Thanks to the kindness of the chief of the *Dirección de Meteorolojica* of Argentina, Señor G. Plate, we have been able to construct various comparative graphs of the fluctuations of pressure in the region of extreme southern South America, the South Orkneys, and South Georgia and have proven that all of the depressions move from west to east, passing between Magellanes and Graham Land, and later, after three to five days according to the velocity of translation, reaching the South Orkneys and South Georgia.

We see, then, that the "parallel" displacement of the depressions as well as the different observations by Simpson rather tend to prove the existence of high pressure in the polar region.

We have the explanation of the cause of this phenomenon in the fact that all atmospheric depressions tend to move toward the "areas of least resistance." If these

areas of least resistance should lie toward the pole the paths of the depressions would be convergent toward that region, but, on the other hand, if the areas of least resistance are found along the line of the ring of low pressure which surrounds the polar area the displacement will take place parallel to the Polar Circle.

With regard to the general circulation of the upper currents of the atmosphere the conclusions reached by Rouch on the Charcot expedition are of notable interest. In summer the mean direction of the cirrus and cirro-stratus clouds was from S. 36° W., in autumn from N. 75° W., in winter from N. 86° W., and in spring from S. 34° W. We see, then, that during the months of spring and summer the paths of the depressions as well as the upper currents of the air are inclined toward the south and that in autumn and winter they are inclined toward the north.

Rouch obtained similar results with the intermediate clouds, cirro-cumulus, alto-cumulus, and alto-stratus; in summer the mean path was from S. 50° W., in autumn from N. 55° W., in winter from N. 60° W., and in spring from S. 59° W.

ANNUAL VARIATION OF THE DIFFERENT METEOROLOGICAL ELEMENTS IN THE ANTARCTIC REGION

The annual variation in the different meteorological elements in the antarctic region is of great importance in studying the fluctuations undergone in the course of the year by the centers of action and the mean path of the areas of low pressure. The most complete series of observations that we have obtained is that made by Rouch on the Charcot expedition.

The atmospheric pressure reaches its crest in the summer months, between October and December, with maximum in the latter month, when the values fluctuate between 740 and 750 mm. (29.13 and 29.53 inches). After January the monthly means of pressure decrease rapidly, reaching the minimum in the autumn and winter months, between April and August, when the barometer fluctuates below 740 mm. (29.13 inches).

The mean monthly temperature remains above the freezing point (0° C.) from December to March, inclusive, but in April it falls abruptly and remains between −5° and −7° C. (23° and 19.4° F.) up to September, inclusive; in October it begins to rise rapidly.

The humidity of the air undergoes very irregular variations; well-defined maxima are observed in January, May, and September, separated by periods relatively less humid with minima in December, February, July, and August. The absolute humidity, however, follows a march entirely parallel to that of temperature.

In Graham Land the prevailing winds during the entire year are from the northeast; they reach their highest velocities at the end of winter and the beginning of spring, with maximum in August. In the summer months the mean velocity of the wind is much lower, with a well-marked minimum in January, when the velocity is only 5 km. (3.1 miles) per hour. In the month of August, on the other hand, the mean velocity exceeds 30 km. (18.6 miles) per hour.

Cloudiness presents a well-defined annual march with maximum in summer and minimum in winter. Mean cloudiness is highest in January (0.9) and lowest in April (0.7). Contrary to what might be expected, fog is by far most frequent in the spring; it has the following distribution by seasons: Summer, 6 per cent; autumn, 15 per cent; winter, 18 per cent; and spring, 34 per cent.

The greatest frequency of precipitation is observed in the months of autumn and spring as is shown by the following: Summer, 23 per cent; autumn, 26 per cent; winter, 24 per cent; and spring, 33 per cent.

The preceding statements relate to "means;" the accidental variations produced by atmospheric disturbances may frequently show extreme values in the antarctic region; in a few days the pressure can change from maxima of 760 mm. (29.92 inches) or higher to minima of 710 mm. (27.95 inches) or lower; the temperature on the Great Ross Barrier may fall as low as −60° C. (−76° F.). The following data will give an idea of the frequency of low minimum temperatures. On an average, the number of days with minimum temperature below −40° C. (−40° F.) is 4 in April, 12 in May, 16 in June, 16 in July, 26 in August, 19 in September, and 2 in October. The mean number of days with temperature below −50° C. (−58° F.) is 1 in May, 6 in June, 3 in July, 15 in August, and 7 in September. It follows that August is the severest month. With regard to wind it frequently happens that velocities of 30 to 40 meters per second (67 to 90 miles per hour) are encountered. The frequency of calms in the different antarctic regions is as follows: Ross Sea, 20 per cent; Antarctic America, 28 per cent; Cape Adare, Victoria Land, 69 per cent.

METEOROLOGICAL PREPARATION FOR AN AERIAL EXPEDITION TO THE ANTARCTIC REGION

After this general résumé of the meteorological conditions in the antarctic region we come to the most important point, that on which depends the success of the expedition; namely, the meteorological preparation for the flights (*raids aeros*).

In this matter I have considered well the results obtained on the two aerial expeditions to the North Pole made by Amundsen. On the first of these expeditions the meteorologist was the distinguished scholar, J. Bjerknes; on the second, Dr. Finn Malmgren, of the University of Upsala.

The results obtained by Bjerknes can be summarized as follows: Experience shows that in areas of low pressure there is much cloudiness and precipitation occurs frequently, while in the areas of high pressure there prevails fine weather with clear skies. Hence the aviator should not take off when a depression is advancing toward the pole and it appears that he will have to pass in the vicinity of the depression. In order to be more or less certain not to encounter foul weather it is important to wait for the approach of high pressure.

Then there is a second very important condition; the anticyclone should be situated to the north of Spitzbergen in order that the explorers shall not be exposed to foul weather after having traveled for several hours through a beautiful, sunny sky. An anticyclone at the North Pole brings northeast winds and low temperature in Spitzbergen. On the western island of this archipelago this northeast wind blows from the land and consequently brings fair weather. On the northern coast its effects are less certain; lifted by this current against the mountains the air rises at some distance from the mountain slopes and in this there is the possibility of the formation of cloud. Ordinarily these clouds cover only a limited area and the aviators pass through them quickly; in any case they can fly over them. It appears that the most certain indication in Spitzbergen of a stable meteorological condition is given by the existence of a northeast wind, prevailing not only at the ground but also at an elevation. When pilot balloons or upper clouds show this régime, they prove the existence of an anticyclone at the pole.

Along general lines we can apply these same conclusions in the antarctic region; the formation of an area of high pressure over Graham Land, with prevailing winds from south to southeast up to high elevations will be evident proof of the existence of an anticylonic régime in the region of the South Pole. However, I consider this insufficient; the meteorologist ought also to foresee the atmospheric changes that may take place in the succeeding 48 hours.

To this end it would be altogether necessary to install a meteorological station, with its corresponding radio station, on the northwest coast of Graham Land as far as possible to the west and far removed from the aerial base of the expedition. As the displacement of the depressions in the far southern region takes place from west to east this station would be able to telegraph daily the approach of the different atmospheric régimes.

The approach of a depression over Graham Land is announced first of all by the appearance of high cirrus clouds and almost simultaneously by a fall in pressure. If the path of the depression passes to the north or to the south of the place of observation there will be a shifting of the wind. If, as it frequently happens, the observer is north of the center of the LOW, the storm begins with wind from the northeast; as the center of the LOW approaches the wind shifts gradually to north, then to west and afterward to southwest and south in the rear of the depression. In the contrary case, the observer being south of the path of the center of the LOW, the storm will begin with wind from east or southeast which gradually changes to wind of great violence from the south when the center passes at the minimum distance. Innumerable examples can be cited from different polar expeditions.

However, the storm may remain stationary, blowing from northeast or south for several days in the special cases in which there is a rapid succession of secondary depressions; in such cases the hurricane lifts whirls of snow which limit visibility to a few meters and throws the pilot off his course. These "blizzards," as they are called, are the most dangerous storms of the polar region, but their prediction is entirely possible.

The data transmitted by the meteorological station situated on the northwestern coast of Graham Land would be supplemented daily by general meteorological information from southern Australia and New Zealand; these data can be of great usefulness in determining well in advance the approach of the periods of atmospheric stability or instability. The expedition led by Señor Pauly will receive regularly at its base station, Deception Island, meteorological reports from the South Orkneys, Ushuaia, and Australia.

Another very important point is the selection of the most favorable time of the year for carrying out the expedition. It will always be necessary to choose the months of greatest atmospheric stability, when fogs are rare and tempests are infrequent. The statistical data indicate that the most favorable months are those of the summer, and not of the spring as is the case at the North Pole. In the former months the frequency of fog is only 6 per cent and the mean velocity of the wind varies between 5 and 20 km. (3.1 and 12.4 miles) per hour.

CONCLUSION

In this paper we have made a general summary of the meteorological conditions in the antarctic region and have discussed meteorological preparations for aerial expeditions to the South Pole. Many details of organizations are omitted; only the general lines are laid down.

Simultaneous observations made in different regions of the antarctic continent have demonstrated that the variations in atmospheric pressure have successively the same sign over Ross Sea, Antarctic America, and Emperor William II Land. When the pressure is high in the antarctic region it is low in the regions more or less in the vicinity of 40° south latitude, and vice versa.

This antarctic region constitutes one of the greatest centers of action on the globe. The polar observations do not merely have unquestioned theoretical interest, but from a practical standpoint they are of exceedingly great importance in weather forecasting in the temperate regions of the Southern Hemisphere, South America especially.

For this reason the expeditions of Pauly and Byrd assume very great importance in the progress of the meteorological world. The *Observatorio del Salto* takes the greatest pleasure in contributing this grain of sand to the realization of this great scientific expedition.—*Translated from the Spanish by W. W. Reed.*

THE SOURCE OF THE WATER VAPOR OF THE ATMOSPHERE: A CRITICISM

ALFRED J. HENRY

It is well known that water vapor is continually passing into the atmosphere from the surface of the seas and lands at practically all temperatures and pressures and is as continually being withdrawn in the form of rain, snow, hail, sleet, and dew. In many respects the circulation of water vapor into and out of the atmosphere is, if not the most important, one of the most far-reaching importance in its effects both from a physical and an economic standpoint. The introduction of water vapor into the atmosphere, in varying quantities is one of the chief means whereby thermal energy is communicated to the upper levels of the atmosphere. The economic importance of a generous supply of water vapor is self-evident.

It is, therefore not surprising that geographers and others from time to time, beginning with Sir John Murray's work in 1887, have sought to determine a balance between the income of water vapor as realized in the phenomenon of evaporation and the outgo in the form of rain, snow, sleet, hail, and dew.

It will be admitted that our knowledge of the amount of precipitation that occurs over the surface of the globe is quite incomplete; there is a distressing lack of information concerning oceanic precipitation. And if so little is known of the distribution of precipitation, still less is known of the amount and seasonal distribution of evaporation over the globe, especially from the water surfaces.

The basic material used in deducing the total precipitation of the globe is, of course, such charts of annual precipitation as may have been prepared and published, and naturally the accuracy of the annual totals of rainfall are directly proportional to the fidelity with which the charts represent the true precipitation of the globe.

In the case of evaporation the circumstances with respect to mapping the distribution of evaporation are such that no attempt as yet has been made to portray the annual amount of evaporation even approximately. The most recent useful contribution on the subject is that of Dr. George Wüst,[1] abstracted in MONTHLY WEATHER

REVIEW, 50:313–14. Doctor Wüst accepts the values for precipitation, run-off and evaporation given by Fritzsche,[2] for the region between 60° N. lat. and 40° S. lat. and supplementing these by assigning values for the regions poleward he arrives at the conclusion that the annual evaporation from the land amounts to 75,000 cu. km. per year or 21,989 cu. km. less than Brückner's determination of an earlier date.

Practically all of the investigators have followed Murray in considering the total quantity of evaporation from land areas as the difference between the total rainfall thereon and the amount of water discharged by the rivers into the oceans.

Each investigator places the total precipitation over the entire earth as equal to the total evaporation. I introduce at this time a small comparative table from Wüst (loc. cit.) giving the results reached by the several students of the problem.

Different determinations of the hydrology of the earth

[Amounts in 1,000 km.³/year]

	Precipitation			Evaporation		
	Fritzsche-Brückner	Schmidt-Fritzsche	Wüst-Fritzsche	Fritzsche-Brückner	Schmidt-Fritzsche	Wüst-Fritzsche
Ocean	353.4	242.4	267.1	384.0	273.0	304.2
Land	111.9	111.9	112.1	81.3	81.3	75.0
Earth	465.3	354.3	379.2	465.3	354.3	379.2

From the above table it may be seen that in general the results of the six investigators as paired by Wüst are mostly in fair agreement; in some cases, however, the disagreements are rather marked, for example, Fritzsche-Brückner estimate the total precipitation of the earth as 465,300 cu. km. while Schmidt-Fritzsche place it at 354,300 cu. km. or 111,000 cu. km. less. Wüst-Fritzsche estimate the total evaporation at 86,100 cu. km. less than Brückner and Fritzsche.

Doctor Wüst is of opinion based on the results of Bigelow's work that it is necessary to apply a reduction factor of 0.82 to Brückner's results making the total oceanic evaporation as given by him 79,800 cu. km. too great. Accepting this criticism the total oceanic evaporation quoted by Zon [3] from Brückner is about 19,000 cu. miles too great. (79,192 cu. km.)

The investigators subsequent to Murray followed his lead in neglecting the amount of water annually devoted to replenishing the water that is very deep in the earth's crust such as artesian flow and that derived from deep wells, 3,000 to 4,000 feet in depth. It is true, of course, that approximate equilibrium in the free water content of the earth's crust has been reached many ages ago; nevertheless it would seem on first thought that very considerable draughts on that supply are made annually and that these amounts must be replenished by rainfall.

Very few worth-while statistics of the draft that is made on the deep earth water supply are available, but using what few can be found, computation shows that the total amount when compared with the total rainfall of the globe may be neglected. At best the water so used is lumped with total evaporation and serves to make that quantity slightly larger than it should be.

I also question the accuracy of the item given by Brückner and quoted by Zon (loc. cit.), viz, "Amount of ocean vapor carried to the land (net)" on the ground that neither the amount of water vapor carried by the atmosphere where it impinges on the land nor the amount of air exchange between land and sea is or can be even approximately known. The best that can be said is that on the average of a number of years the amount of exchange of air is substantially the same.

The unfortunate thing about the statement above quoted and others of like character which occasionally come from persons of high standing in their chosen professions is that the lay reader frequently does not and can not distinguish between the sound and the unsound when matters concerning the physical properties of the atmosphere are concerned.

Another statement by Brückner which in the original is quite correct, but by the suppression of a modifying clause is erroneously interpreted, is the emphasis placed on the importance of land masses as furnishing a supply of water vapor that is later condensed and falls as rain or snow.

I quote a translation of his words and have italicized those most generally omitted in quotations.

> Not ineffective is the rôle which the land surface plays in the circulation; on a mighty scale it adds to the moisture content of the air; nearly two-thirds of the rain falling on land comes from the masses of vapor furnished by itself and is thus of continental origin. *To be sure, the ocean is the source of these masses of vapor;* it furnishes a certain amount of water which repeatedly changes position over the land, here rather rapidly, there more slowly, and thus enters many times into the phenomenon of precipitation. (Geographische Zeitschrift, Vol. VI, p. 96.)

In discussing this subject with my colleague, Dr. W. J. Humphreys, he reverted to the fact that some years ago, to be precise, in 1914, he had drawn up a concise statement of the relations between world evaporation, precipitation, and run-off. Doctor Humphreys has kindly consented to the publication of this statement. See the succeeding article.

[1] Die Verdunstung auf dem Meere. Veröff. d. Inst. f. Meerskunde, N. F. Reihe A Heft 6 1920 (S85).
[2] Niederschlag, Abfluss und Verdunstung an freien wasserflächen ein Beitrag zum Wärmehaushalt des Weltmeeres und zum wasser haushalt der Erde. Ann. d. Hydrog. usw. 1915.
[3] Zon, Raphael, Final Report National Waterways Commission, 1912. (Zon's article in this report was recently reprinted.)

SOME RELATIONS BETWEEN EVAPORATION, PRECIPITATION, AND RUN-OFF

By W. J. HUMPHREYS

Many efforts have been made to find important relations between evaporation, precipitation, and run-off, but while such relations can be found it nearly always happens that it is impossible to deduce from them the value of any one of the quantities in terms of measurable values of the others. The restricted range and application of these relations will be clear from the following:

(1) *For the world as a whole.*—Evaporation = Precipitation.

(2) *For all land areas jointly.*—

Let P_o = precipitation coming from ocean evaporation.
P_L = precipitation coming from land evaporation.
$P = P_o + P_L$ = total precipitation over land.
R_s = surface run-off.
R_u = underground run-off.
R = total run-off.
E = total land evaporation.
Then $P_o = R$; $P_L = P - R = E$.

That is to say, the greater the precipitation on the land the larger the evaporation from it, unless the increase in run-off equals the increase in the precipitation, which we know in general it does not. This, however, does not prove that the precipitation is to any extent increased by the land evaporation—though there are good reasons for thinking that it is. If it does not increase land precipitation it must then increase ocean precipitation, for total evaporation from land and ocean must equal total world precipitation. But, as implied, it is preactically certain that, owing to vertical convection caused by surface heating and by mountain ranges, land evaporation increases land precipitation more than ocean precipitation.

(3) *For a restricted area—a given watershed, say.*—

Let V_i = amount of vapor brought by winds to the given region in a year.

V_o = amount of vapor carried by winds from the given region in a year.

p_1 = amount of precipitation from vapor V_i on the given region in a year.

p_2 = amount of precipitation from evaporation over the given region in a year.

$P = p_1 + p_2$, or total precipitation on the given region in a year.

R_s = surface run-off from the given region in a year.

R_u = underground run-off from the given region in a year.

$R = R_s + R_u$, or total run-off from the given region in a year.

E = evaporation from the given region in a year.

Then $V_i - V_o = R_s + R_u < p_1$, because some of the local precipitation is supplied by local evaporation, as in heat thunderstorms, for instance; $P - (R_s + R_u) = E > p_2$, since some of p_1 also is evaporated. These seem to be the only useful equations available between the terms given. In a closed basin where $R = 0$, $E = P$; in an open basin, $E = P - R$. Some measurements indicate that at places P may be several fold R. Say, $P = AR$, then $E = (A-1)R$. But P and R_s are measurable, and often the value of R_u can be approximated—seldom more, perhaps, than 1 per cent of R_s. Hence, a more or less accurate value of E is determinable.

In regard to a restricted area we can only say that the evaporation is a result of the precipitation—we can not say to what extent the local precipitation is a result of local evaporation.

It is obvious, however, that evaporation from vegetation and from the soil often is very great—the temperature of the air frequently is high (many degrees higher than over the ocean at the same latitude), the tree foliage is well up in the atmosphere, and finally the air is well mixed—more so than over the ocean. For all these reasons—high temperature, elevation of evaporation surfaces, and mixing of air—it seem certain that, when moist, land evaporation must be great and free. It is also obvious that this evaporation must increase leeward precipitation, but to what extent does not at present seem determinable.

That local evaporation increases leeward precipitation seems to be the logical explanation, at least in part, of, among other things, the facts (*a*) that "all signs fail in dry weather"; (*b*) that "during wet weather it can rain without half trying"; and (*c*) that in the case of a rapid succession of rain storms passing over a semiarid region, each penetrates farther than its predecessor. Professor Henry has called my attention to examples of (*c*) on the Pacific coast of the United States.

PRECIPITATION, EVAPORATION, AND RUN-OFF

By W. J. HUMPHREYS

Dr. C. E. P. Brooks's timely and admirably conservative paper on the influence of forests on rainfall and run-off [1] appears to offer a possible means of determining relations between precipitation, evaporation, and run-off that after all may not be as reliable as it seems. This is not a criticism of his fine contribution to an intricate subject, but rather a reminder of an inherent difficulty that no one yet has managed to solve.

Let all quantity symbols refer to the average amount per second. Let P be the total precipitation per second, as specified, over the land; R, the run-off; and E, the evaporation; then

$$P = R + E$$

Some of E is reprecipitated on the land—call it P'; and some, x, is not. Hence

$$P = R + P' + x \qquad (1)$$

and

$$P - P' = R + x$$

If V_{op} is the amount of on-shore vapor that is precipitated onto the land and V_o the amount of on-shore vapor that is not so precipitated; and, finally, if the total amount of water vapor coming to the land from the ocean is n times the amount leaving the land, then

$$V_{op} = R + x$$

$$V_o + V_{op} = n\,(V_o + x)$$

and

$$x = \frac{R}{n-1} - V_o$$

If n is 2, a reasonable assumption suggested by Brooks,

$$x = R - V_o;$$

but we have no means by which to determine V_o, hence x also is unknown. Brooks appears to assume that V_o is negligible and thus gets the relation

$$x = R.$$

On substituting this value of x in (1), it would seem that the precipitation on the land due to evaporation from the land is equal to the *total* precipitation thereon less twice the run-off; or, in symbols, that

$$P' = P - 2R.$$

Actually, though,

$$P' = P - \frac{n}{n-1}R + V_o$$

But, as stated above, V_o is unknown; therefore P' also is unknown. And the more significant the value of V_o the less reliable any estimate we may make of P'.

[1] *Q. Jr. Roy. Meteorol. Soc.*, 54, 1, 1928.

SOLAR RADIATION IN MIDDLE NORTH GERMANY ACCORDING TO MEASUREMENTS AT POTSDAM

[*Meteorologische Zeitschrift*, January, 1928]

By JOHANN SCHUBERT

The intensity of solar radiation at the surface of the earth is determined by the intensity at the outer limit of the atmosphere and by the loss sustained in the path through the air even when the sky is perfectly clear.

The amount of heat which the unit surface receives in the unit of time with normal incidence of the sun's rays is called full radiation, intensity in the direction of the sun's rays, or total intensity. The radiation upon a surface whose normal forms an angle with the direction of the rays, or the radiation component in the direction of this normal, follows from projection.

Calculations of the solar radiation for different latitudes and also for surfaces with different slope and exposure (*Himmelsrichtung*) are often undertaken without reference to the atmosphere and, at times, even without regard to the changing distance of the sun under the simple assumption, which by no means corresponds to fact, that the full radiation is constant at the bottom of the sea of air. Eser [1] calculated for the latitude of Munich the duration and daily totals of radiation on planes of different slope and exposure taking as a unit radiation at normal incidence for the period of one hour. Others [2] have developed similar formulas or graphic methods. Recently Gessler [3] has renewed and extended such calculations, and Hopfner has published as a supplement to an older work [4] a voluminous, orderly, and highly commendable prize paper on solar radiation [5] in which the sun is assumed to be a point-like source of light with constant energy and the earth is considered as having no atmosphere.

In order to take account of the depletion of solar radiation [6] in the earth's atmosphere it has been assumed, after the example of Lambert (1726), that in the passage through equal air masses the radiation is diminished to the same fractional part, which holds, to be sure, only for homogeneous radiation. Especially through the work at the American observatories, which are thoroughly equipped and favorably located (some at great elevation above sea level) has it become possible to determine the degree of transmissibility of the different wave lengths, to take account of the influence of water vapor and dust, and to determine accurately, to within 1 per cent, in absolute quantity the mean intensity of the solar radiation outside the earth's atmosphere; that is, the solar constant.[7]

By careful, extensive observations at a series of places the actual solar radiation at the earth's surface has been determined for different elevations of the sun and different seasons. Through the exact measurements of W. Marten at the Potsdam Observatory during the period 1907 to 1923 there has been determined the daily and yearly march of solar radiation in middle North Germany, which forms a reliable basis for further investigation.

The question of the radiation on surfaces of different slope and exposure can now be answered unequivocally. The values of full radiation with cloudless sky presented in this paper are taken from W. Marten's work, *Das Strahlungsklima von Potsdam*.[8] Berlin, 1926. For the declination of the sun (δ) values are taken from the *Nautisches Jahrbuch* for 1925; such values agree well with the average for the period of observation. The latitude of Potsdam (φ) is 52° 23′; the hour angle (t) is counted from noon. The point of observation lies (since 1909) about 106 meters above sea level and about 25 meters above the ground.

We resolve the full radiation, or total intensity, J, into a vertical component Z (directed downward from the zenith) and a horizontal component or intensity H; the latter is resolved into a south component (intensity of radiation from south to north) X and a west component Y. Denoting the sun's elevation by h and its azimuth by A, we have [9]

$$H = J \cos h.$$
$$X = J \cos h \cos A = J\,(-\sin\delta \cos\varphi + \cos\delta \sin\varphi \cos t).$$
$$Y = J \cos h \sin A = J \cos\delta \sin t.$$
$$Z = J \sin h = J\,(\sin\delta \sin\varphi + \cos\delta \cos\varphi \cos t).$$

These formulas give radiation for the following surfaces: X, south wall; Y, west wall, and Z, horizontal plane.

The radiation on any plane whatever or the intensity in the direction of its normal can be constructed from these components, for example:

Southeast wall, $(X-Y)\cos 45°$.

South slope of 30°, $X \sin 30° + Z \cos 30°$.

Southeast slope of 20°, $(X-Y)\cos 45° \sin 20° + Z \cos 20°$.

The values of full radiation with cloudless sky are calculated symmetrically with reference to true noon by taking together each of the two hours equidistant from noon. A preliminary investigation to determine the finer differences between forenoon and afternoon was made by Marten (*Das Strahlungsklima*). According to that the highest values shift to the forenoon in summer and to the afternoon in autumn by an hour or less.

The values of solar radiation on cloudless days are multiplied by the duration of sunshine to obtain the radiation values with mean cloudiness. In addition values for the middle point of time were calculated from the sums of the duration of sunshine for four adjacent hours m_0, m_1, m_2, and m_3 according to the formula [10]

$$\frac{m_1+m_2}{2} + \frac{1}{6}\left(\frac{m_1+m_2}{2} - \frac{m_0+m_3}{2}\right).$$

Values for early and late hours were determined approximately; the recorded data on duration of sunshine were

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[1] Eser, C. Forschungen aus dem Gebiete der Agrikulturphysik, herausgegeben von E. Wollny, 1884, Bd. 7, p. 100; Zeitschrift der Österreichischen Gesellschaft für Meteorologie, 1885, Bd. 20, p. 71.

[2] Steiner, L. Meteorologische Zeitschrift, 1898, p. 103 and 1906, p. 294; Zöllner, S. Meteorologische Zeitschrift, 1906, p. 92. The intensity with normal radiation is considered constant.

[3] Gessler, R. Abhandlungen des Preussischen Meteorologischen Instituts, Bd. VIII, Nr. 1, Berlin. 1925. One equator-hour is taken as the unit of full radiation constantly received.

[4] Hopfner, F. Meteorologische Zeitschrift, 1906, pp. 384 and 396.

[5] Hopfner, F. Gerlands Beiträge zur Geophysik, 1926, Bd. 15, pp. 116 ff.

[6] Hann, Julius. Handbuch der Klimatologie, 3d. I, p. 93; Hann, Julius and Süring, R. Lehrbuch der Meteorologie, 4th edition, pp. 24, 801, 806.

[7] See papers on solar radiation (Sonnenstrahlung) listed in the index volume (1881-1908) of the Meteorologische Zeitschrift, also the following papers in that publication: Maurer, J., 1912, p. 561, and 1916, p. 103; Defant, A., 1913, p. 289; Fowle, F. E., 1914, p. 270; Hann, Julius, 1916, p. 79; Defant, A., 1916, p. 211; Kron, E., 1916, p. 228; Kimball, H. H., 1916, p. 377, and 1918, p. 144; Marten, W., 1920, p. 252; Ångström, A., and Dorno, C. 1921, p. 38; Dorno, C., 1922, p. 303; Dietzius, 1923, p. 161. Also Sonnen-und Himmelstrahlung in the indexes to the Meteorologische Zeitschrift for 1924 ff.

[8] Abhandlungen des Preussischen Meteorologischen Instituts, Bd. VIII, Nr. 4; Ergebnisse (d. Preuss. Meteorol. Inst.) 1908, p. XXIII and 1912, p. XI.

[9] Brünnow, F. Lehrbuch der sphärischen Astronomie, 4th edition, p. 81; Hammer, E. Lehrbuch der Trigonometrie, 2d edition, p. 511.

[10] Schubert, J. Der jährliche Gang der Luft-und Bodentemperatur. p. 32. Berlin. 1900.

supplemented by reference to measured values of radiation.

The paper then presents in tabular form [11] the values of radiation, in gram-calories per minute per square centimeter, with clear sky and with mean cloudiness received at Potsdam at each hour of the day at the middle of each month of the year on ten differently exposed surfaces as follows: Plane normal to the direction of the rays (total intensity), horizontal plane, walls facing north, east, south, and west, and slopes of 30° facing the above directions.

From values for clear sky there has been constructed for presentation here Table 1 showing values of radiation at 11 a. m., when the intensity of full radiation is only slightly below the maximum.

The maximum values of solar radiation with clear sky under different exposures are given in Table 2. It is to be noted that these values like those preceding relate to the middle of the month.

Table 3 (part of Table 5 in the original paper) gives solar radiation with average cloudiness, the actual radiation received, at Potsdam during one day at the middle of each month of the year.

Assuming that the mid-month values are average values for the month, Schubert presents a table of mean daily amounts of solar radiation received with clear sky and also with average cloudiness (at Potsdam) during the period from April to August, inclusive, which he calls the main growing season (*Hauptvegetationzeit*). These values which are of special interest to the agriculturist, are given in Table 4.

—Selected text translated by W. W. R.

TABLE 1.—*Solar radiation (gram-calories per minute per square centimeter) with clear sky at 11 a. m. at the middle of the month. Potsdam*

Exposure	January	February	March	April	May	June	July	August	September	October	November	December
Under normal incidence (total intensity)	0.98	1.11	1.11	1.26	1.28	1.27	1.19	1.15	1.21	1.16	0.97	0.93
On horizontal plane	.26	.45	.62	.90	1.04	1.08	1.00	.88	.77	.54	.30	.21
On east wall [1]	.24	.28	.29	.32	.31	.32	.29	.29	.31	.30	.24	.22
On south wall	.91	.98	.87	.82	.67	.58	.58	.68	.89	.98	.89	.88
On north slope of 30°	.00	.00	.10	.37	.56	.65	.58	.42	.22	.00	.00	.00
On east slope of 30° [2]	.34	.53	.68	.94	1.06	1.09	1.00	.91	.82	.62	.38	.29
On south slope of 30°	.68	.88	.97	1.19	1.24	1.23	1.15	1.11	1.11	.96	.71	.62
On west slope of 30° [3]	.10	.25	.39	.62	.74	.79	.72	.62	.51	.32	.14	.07

[1] On west wall at 1 p. m. [2] On west slope of 30° at 1 p. m. [3] On east slope of 30° at 1 p. m.

[11] Also in isopleths for radiation with clear sky.

TABLE 2.—*Maximum values of solar radiation with clear sky for different exposures (gram-calories per minute per square centimeter). Potsdam*

Exposure	Radiation in gr.-cal. min. cm.[2]	Month	Hour
Under normal incidence	1.278	May	Noon.
On horizontal plane	1.113	June	Do.
On north wall	.250	do	5 a. m.[1]
On east wall	.911	do	7 a. m.
On south wall [3]	1.019	October	Noon.
On west wall	.911	June	5 p. m.
On north slope of 30°	.654	do	Noon.
On east slope of 30°	1.156	do	10 a. m.
On south slope of 30°	1.276	May	Noon.
On west slope of 30°	1.156	June	2 p. m.

[1] Also 7 p. m. [2] 1.016, February, noon.

TABLE 3.—*Solar radiation (gram-calories per square centimeter), with average cloudiness, received daily at the middle of the month. Potsdam*

Exposure	January	February	March	April	May	June	July	August	September	October	November	December
Under normal incidence	84	134	226	354	441	489	414	375	329	212	95	70
On horizontal plane	20	44	102	196	276	319	269	223	165	81	25	15
On north wall	0	0	0	1	11	23	14	4	0	0	0	0
On east wall	13	29	61	106	133	148	122	112	91	49	17	10
On south wall	74	106	146	158	136	120	113	143	184	157	82	65
On west wall	14	29	56	99	126	139	121	106	88	49	18	12
On north slope of 30°	0	0	15	91	176	228	183	124	50	0	0	0
On east slope of 30°	18	42	96	182	251	289	240	204	153	76	24	14
On south slope of 30°	54	91	161	248	303	326	283	263	235	149	63	45
On west slope of 30°	19	42	92	175	245	281	239	198	149	76	25	15

TABLE 4.—*Mean daily total of solar radiation (gram-calories per square centimeter), with clear sky and with average cloudiness, April–August. Potsdam*

Exposure	Radiation in gr.-cal. min. cm.[2]	
	Clear sky	Average cloudiness
Under normal incidence	869	415
South slope of 30°	563	285
Horizontal plane	512	257
East slope of 30°	469	233
West slope of 30°	469	228
North slope of 30°	329	160

THE ROOT PROBLEM OF MACRO-METEOROLOGY

By DR. FRANZ BAUR

[Berlin, Germany, April 10, 1928]

SYNOPSIS

The root problem of macro-meteorology is the answer to the question: Are the changes in the system of the general circulation of the atmosphere, to which after all the great weather abnormalities are traceable, occurrences which originate in the main in themselves, or is their origin for the most part to be looked for outside the earth? The purpose of the following investigations is to help to pave the way to the right answer to this fundamental question. It is therein shown that it can not be proved that there is any connection between changes in atmospheric circulation and cosmic occurrences, especially solar ones; it is shown, however, that there is a close connection between these changes on the whole and the foregoing temperature and pressure abnormalities on the earth itself. Changes in solar radiation have an influence worth mentioning on the general circulation of the atmosphere only when they find a resonance in the complex wave system of atmospheric circulation.

We know that great weather phenomena (macro-phenomena, by which I understand, not the weather of single days, but the general character of the weather extending over a longer period, say of weeks and months) stand in closest relationship with the great variations in the general circulation of the atmosphere and their single parts. The idea of the general circulation of the atmosphere comprises in this connection a whole complex of phenomena, viz, the exchange of air between the

subtropical belts of high pressure and the equatorial zone, which takes place with relative regularity even if not at all always continuously, and the naturally discontinuous exchange of air between the subtropical and the polar regions which takes place in several contig ous "Zirkulationsstreifen" (1). For the understanding and forecasting of the great weather phenomena, the question of the *origin* of the great changes in the general circulation of the atmosphere and their single parts, is of fundamental importance. Two possibilities exist. *Either* it is a question of the *changes having for the most part their origin in themselves;* that is, according to which the condition B at any given point of time is determined by the foregoing condition A (terrestrial); *or*, the *origins* of these variations are *for the most part* to be looked for *beyond the earth*. The question as to which of these two possibilities is to be accepted as correct is the *fundamental question of macro-meteorology*.

If cosmic influences are chiefly responsible for the condition of the weather on the whole, then it is most probable that these influences consist of changes in solar radiation beyond the earth, since all changes in our atmosphere derive their energy from solar radiation. It is indeed often supposed that the great variations in the intensity of the general circulation of the atmosphere are determined by changes in extraterrestrial solar radiation. An exact examination of this supposition in the light of experience is not yet possible, since we have too little information about the actual changes in solar radiation. Certain points can however be deduced on the ground of some considerations which allow us to form a judgment on the question of whether the influences of possible changes in solar radiation are of *prime* or only subordinate importance.

The *first consideration* of this sort is the following: If changes in solar radiation, quantitative or qualitative, of any importance take place at all, these are very likely connected with *visible changes* in the sun's surface. We know to-day five such changes, namely, sun spots, faculæ, protuberances, the changing form of the corona, and the so-called solar contrast (i. e. the contrast between the brightness of the edge and center). The frequency of the faculæ changes almost exactly parallel with the sun spots. For the period 1887–1924, I found for the annual mean of numbers of sun spots and faculæ a correlation coefficient of *+0.89*. The changing form of the corona also stands in close covariation with the sun spot period. If solar activity is less, long rays are found parallel to the sun's equator, corresponding to the fact that then the spots occur in lower heliographic latitudes. If the number of spots is however great, so that they appear in higher latitudes, then the rays of the corona stretch out in all directions fairly evenly into space. Similarly, the frequency of the protuberances and the strength of the solar contrast appear to be connected with the frequency of sun spots. We can therefore obtain a general statistical survey of the different visible changes in the sun's surface, by selecting the sun spots, which have been longest under observation and which can be best expressed numerically. Accordingly, I examined by means of the correlation method, whether any connection exists between the number of sun spots and the intensity of the North Atlantic atmospheric circulation, which is a part of the general circulation which splits into single contiguous "Streifen" (stripes) in the temperate zone. As a measure of the intensity of the North Atlantic atmospheric circulation, I chose the pressure difference between Ponta Delgada and Iceland. (2)

In the first column of Table 1 occur the correlation coefficients between the monthly means of the difference of pressure Ponta Delgada-Iceland and the monthly means of Wolfer's numbers of sun spots occurring *simultaneously*, for every month of the year in the 50-year period 1874–1923. Any systematic relation is *not* apparent. With the exception of the coefficient for May they are all very small. In answer to the interpretation of this result as evidence that no connection worth mentioning exists between sun spots and intensity of atmospheric circulation, it can be put forward that there need not necessarily be the connection with the sun spots visible at the moment. v. Aufsess (3), for example, supposes that sun spots affect the weather only as long as they are in the process of formation, and not yet visible to the eye. I have therefore also calculated the correlation coefficients between the monthly means of the pressure difference Ponta Delgada-Iceland and the increase in the number of sun spots *from* the *past* and *up to* the *next* month. The resulting coefficients occur in the second and third columns of Table 1. Here also only small coefficients were found, and *no* systematic connection. Out of 36 coefficients in Table 1, there are 3 which exceed twice the standard error, that is, only a single one more than could be expected with a distribution of the coefficients according to Gauss' Law. It is to be noticed that the large coefficient of the second column is not independent of that in the first column.

Since, strictly speaking, lower correlation coefficients do not yet mean that no connection whatsoever exists between two phenomena, but only that this is no rectilinear relation, I have also calculated the correlation ratios which are a measure of the closeness of the connection for every kind of law of dependence. Here also the result was that *no connection* could be proved between sun spots and intensity of North Atlantic air circulation.

The *second consideration* with the help of which we are able to form a judgment as to whether the great variations in the general circulation of the atmosphere are caused chiefly by changes in solar radiation, is that a change in the solar constant, or a change in the diathermancy of the atmosphere caused by an extraterrestrial influence, will change the intensity of the air circulation, not in all parts in the same degree, but at least *in the same sense*. If, for example, through an increase of temperature in lower latitudes which has its origin, not in limited local conditions, but in changes in extraterrestrial solar radiation, an increase in the atmospheric circulation in the North Atlantic "Zirkulationsstreifen" is caused, there is no reason why such an increase should not also be apparent in the North Pacific "Zirkulationsstreifen," even if the amount of increase may be different here and there. There would have to be, therefore, if the changes in solar radiation are of determining importance, positive correlations of the intensity of circulation between the individual "Zirkulationsstreifen" and—at least in the winter half year in the southern hemisphere—positive correlations of pressure between the nuclei of the subtropical belt of high pressure.

A comparison of the west component of the windways in Potsdam (Germany) and in Boston (Mass.) produced (4) a distinct positive correlation, because both belong in general to one and the same "Zirkulationsstreifen." Especially clear is the correlation of the southwest component in Potsdam and the northwest component in Boston, to be explained by the fact that Potsdam lies on the east side and Boston on the west side of the North Atlantic "Zirkulationsstreifen". On the other hand, no

correlation exists between the windways over Potsdam and those of Portland (Oreg.) in the west of North America, and none between the windways of Boston and Portland, just because Portland belongs to a different "Zirkulationsstreifen," that of the North Pacific.

The comparison of *contemporary changes of pressure* in several places lying in the *subtropical region of high pressure* has been made for the southern hemisphere, since the subtropical region of high pressure in the northern hemisphere, on account of its great land masses (chiefly Asia) extending into high latitudes, is less regular and less clearly defined. In order to obtain a reliable result, observations extending over 50 years were made use of for this purpose. For this reason Cape Town and St. Helena on the border of the South Atlantic anticyclone had to remain out of consideration, since of both places no such long *homogeneous* series are available. The chosen places Buenos-Aires and Cordoba, Mauritius and Sydney (Austral.) lie, in the winter half year, in the middle of the southern high pressure region. There would have to be therefore, at least in winter, positive correlations of the contemporary monthly means of air pressure for these places, if the whole region of high pressure experiences uniform changes of intensity. Instead of this, however, as Table 2 shows, the correlation between the atmospheric pressure at Sydney (Austral.) and that in the Argentine (Buenos Aires + Cordoba) is negative almost throughout the whole year, especially, however, just in winter; also the correlation of the Argentine with Mauritius is for the most part negative. The correlation of the air pressure over Mauritius with that over Sydney is, maybe, more often positive than negative, but the largest positive coefficients are found, not for the winter proper (June-August), but for the transition months March and September. Among the 36 coefficients of Table 2 occur five which exceed twice the standard error m, whilst in Table 1 only three such coefficients appeared, and with accidental distribution (distribution according to Gauss' Law) the probability of a correlation coefficient 2 m is 1:22. It is therefore quite possible that in the five largest correlation coefficients physical relations which really exist between the pressure of the three chosen parts of the southern high pressure belts are expressed; but these relations are not of the kind enabling one to speak of uniform variations of intensity of the whole high pressure region.

These examinations showed that *no connections* exist admitting of the conclusion that the great changes of intensity in the exchange of air in the "Zirkulationsstreifon" are determined for the most part by changes in solar radiation reaching the earth. What can now be said about the connection between changes in circulation abnormalities *and foregoing conditions in the atmosphere itself?*

In order to make this clear, we can first put the *preliminary question, "Does the distribution of air masses in the northern hemisphere exercise a systematic influence on the intensity of the North Atlantic atmospheric circulation, either to preserve or change it?*

In answer to this question, the average departure of pressure was calculated for 44 stations in the northern hemisphere for the period 1887/1916.

(*a*) In those months in which the North Atlantic atmospheric circulation was especially intensive, and also remained the same in the next month.

(*b*) In months with very intensive circulation, followed by a considerably too weak circulation.

(*c*) In months with very weak circulation which remained unchanged in the next month.

(*d*) In months in which the North Atlantic atmospheric circulation was very weak, whilst it was in the following months considerably too intensive.

It was regarded as a considerable deviation from the normal circulation when, in the first month for which the distribution of pressure was calculated, the departure from the normal pressure gradient between Ponta Delgada and Iceland in the months October–April amounted at least to 4 mm., and in the months May–September, 3 mm., whilst in each case for the succeeding month 2 or 1.5 mm. were taken as the minimum.

The results obtained for February are shown in Figures 1–4. Figure 1 shows how, in those months of February, in which an especially intensive North Atlantic atmos-

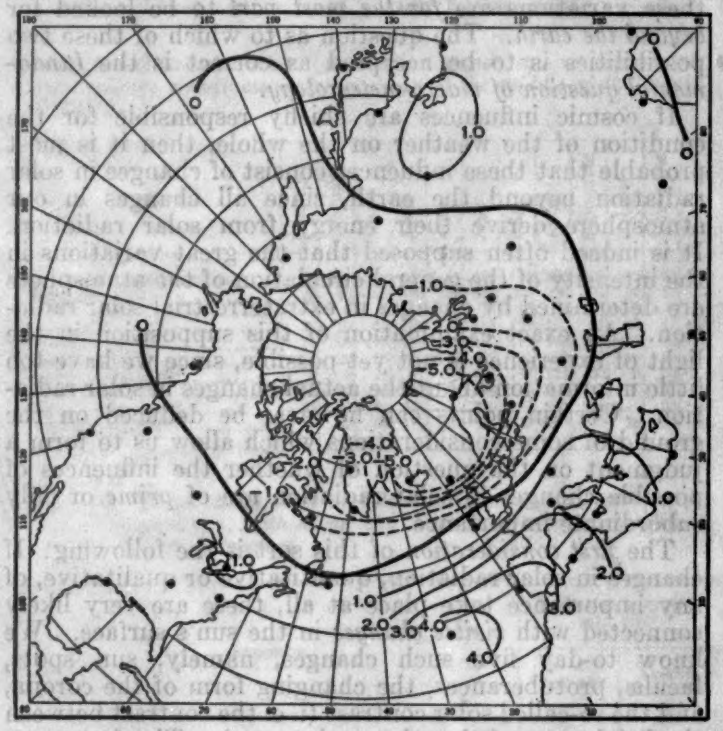

FIG. 1.—Mean pressure departures (mm.) in February, 1894, 1897, 1903, 1907, 1908, 1910, and 1914, with very *strong* North Atlantic air circulation, which *continued* during the succeeding March

pheric circulation was followed by an equally intensive one in March, a limited region of deficient pressure occurs round the pole; whilst in middle and lower latitudes a belt of excess pressure lies. The reverse abnormality is seen in Figure 2—around the pole a region of excess pressure and in lower latitudes deficient pressure. This distribution of pressure exists with very weak North Atlantic air circulation, which continues during March. Figure 3 presents a totally different picture. It represents the abnormality of those months of February with very strong North Atlantic circulation, which *changes* in March to one of little intensity. Here we have an arrangement of regions of abnormalities, not in zones but in meridional stripes. To the great contrasts in pressure in one and the same latitude, correspond, as is shown by the carrying out of the same investigations for temperature abnormalities (5), similar contrasts in temperature. In a similar manner, positive and negative abnormalities of pressure alternate in Figure 4 in one and the same latitude; but here, in contrast to Figure 3, near Iceland, excess pressure exists, corresponding to the circumstance that Figure 4 represents the mean departures of pressure with very weak North Atlantic circulation in February changing to strong in March. Similar results were found for the other months of the year (5).

The *fundamental difference* between the distribution of pressure in the case of the continuation of the existing abnormality of circulation and that before the coming of

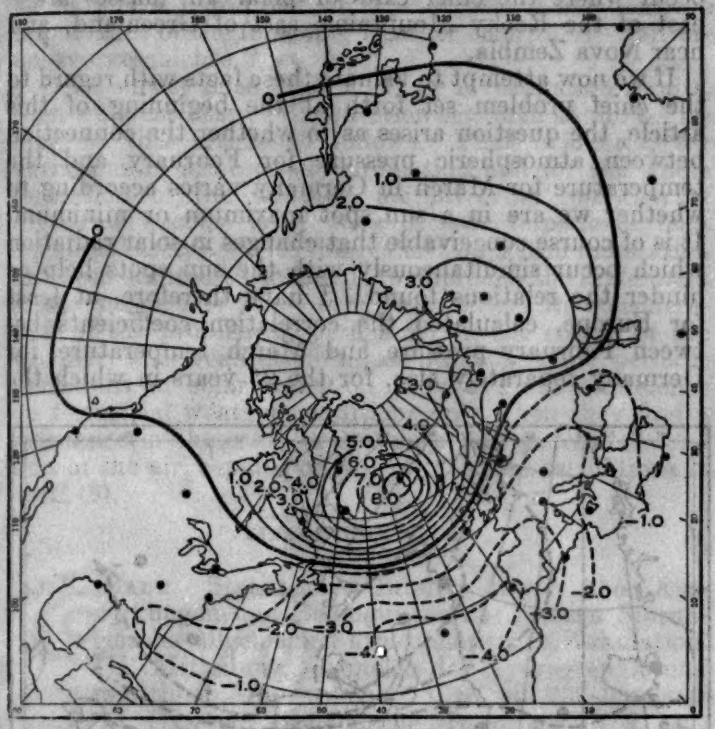

FIG. 2.—Mean pressure departures (mm.) in February, 1888, 1892, 1899, 1900, and 1901, with very *weak* North Atlantic air circulation, which *continued* during the succeeding March

a change from deficient to excessive circulation intensity or vice versa is that in the first case the meridional gradients are above or below normal, in the latter case

FIG. 3.—Mean pressure departures (mm.) in February, 1887, 1898, 1906, 1915, and 1916, with very *strong* North Atlantic air circulation which changed to one of little intensity in the succeeding March

the zonal. Through the abnormal zonal gradients of pressure abnormal meridional displacements of air are naturally caused, which bring about the change in circulation abnormality. We can, therefore, on the ground of these results answer the above preliminary question as follows: *Whether an existing abnormality in the North*

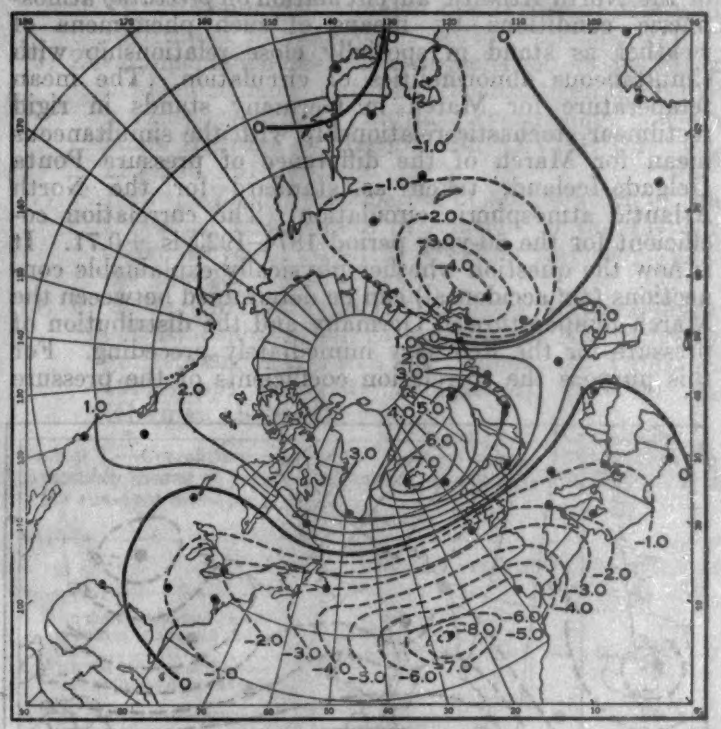

FIG. 4.—Mean pressure departures (mm.) in February, 1890, 1895, 1902, and 1912, with very *weak* North Atlantic air circulation, which *changed* in the succeeding March to a strong one

Atlantic air circulation (apart from temporary changes caused by passing waves of pressure) *continues for a still longer time, or is reversed, depends essentially on whether*

FIG. 5.—Lines of equal correlation coefficients between the February mean values of pressure and the temperature in the following March in the 50-year period 1874–1923

the whole polar region shows a uniform abnormality of pressure, or whether zonal contrasts exist in the pressure deviation of higher latitudes. We have here then an evident

dependence of changes in atmospheric circulation on preceding *terrestrial* conditions.

We can also verify the great dependence of the intensity of the North Atlantic air circulation on *preceding* atmospheric conditions by means of such phenomena of weather as stand in specially close relationship with simultaneous abnormalities of circulation. The mean temperature for March in Germany stands in rigid rectilinear stochastic relationship with the simultaneous mean for March of the difference of pressure Ponta Delgada-Iceland, taken as standard for the North Atlantic atmospheric circulation. The correlation coefficient for the 50-year period 1874–1923 is +0.71. It is now the question whether physically explainable connections (*not* accidental) can be determined betweeen the March temperature of Germany and the distribution of pressure for the February immediately preceding. For this purpose the correlation coefficients of the pressure

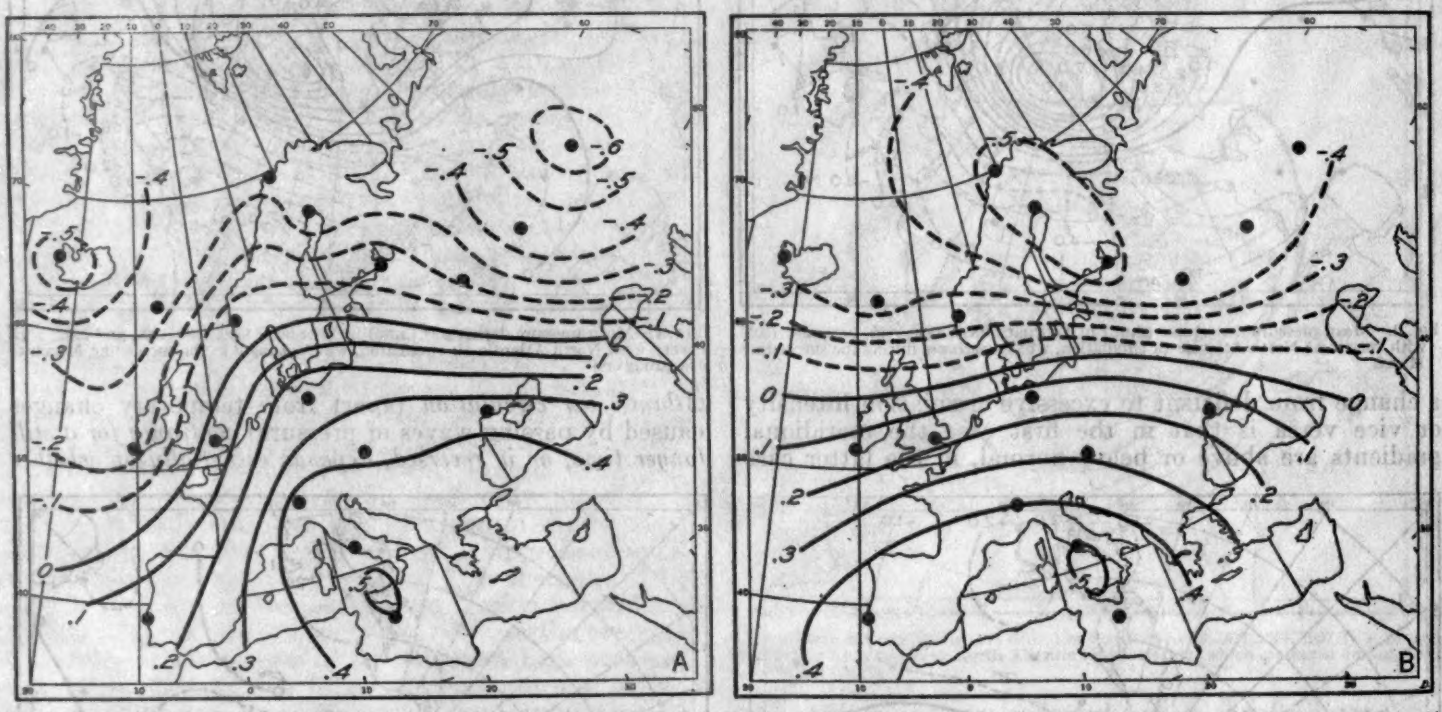

FIG. 6.—Lines of equal correlation coefficients between the February pressure and the temperature in Germany in the following March; A, in months *below* normal sun-spot activity, and B, in months *above* normal sun-spot activity

for February for the period 1874–1923 were calculated for 38 stations in the Northern hemisphere with the temperature of Germany in the following March. The result is set forth graphically in Figure 5. This figure gives a quite clear picture; positive correlation with the pressure in Middle and South Europe, negative corrrelation with the pressure in higher latitudes from North America to the Yenesei. The correlation coefficients are for certain places very considerable, e. g., Rome +0.48, Malta +0.48, Sswerdlowsk (the former Katherinburg on the east slope of the Ural Mountains) −0.52, Kem (on the White Sea) −0.57. That this is not accidental we see from the fact that we get for the two separate 25-year periods 1874–1898 and 1899–1923, at least for the European-Asiatic part, almost the same correlations. With regard to a detailed mathematical criticism of the stability of the correlation, reference must be made to the original work (6).

It is especially to be noticed that the nuclei of high correlation are without exception to be found in prominent places (places having especial meteorological importance), the highest positive correlation where at this time of year there is a root region of stratospheric pushes toward the north whilst the nuclei of negative correlation occur where the chief exits of polar air masses are—east of the Rocky Mountains, east of Greenland, and near Nova Zembla.

If we now attempt to valuate these facts with regard to the chief problem set forth at the beginning of this article, the question arises as to whether the connection between atmospheric pressure for February and the temperature for March in Germany varies according to whether we are in a sun spot maximum or minimum. It is of course conceivable that changes in solar radiation which occur simultaneously with the sun spots help or hinder the relations found. I have therefore, at least for Europe, calculated the correlation coefficients between February pressure and March temperature, for Germany separately also, for the 25 years in which the numbers of sun spots in March were above normal, and for those 25 years in which they were below normal. In doing this the mean values for the thus selected 25 per cent years were naturally used as a starting point. As a secondary result it was found that, in accordance with former investigations (1), that the differences in the mean values for months of maximum and minimum sun spots respectively, are only *very slight*. The mean temperature for March is for example (in Germany) in the months of maximum sun spots only about 0.30° C. less than in the months of minimum spots.

The correlation results in the months with below normal and above normal sun-spot activity are set forth graphically in Figures 6 and 7. A difference between the two sets of results exists only in so far as the largest negative correlation lies in the one case, when sun spots are numerically above normal, in North Scandinavia and Finland; in the other case, when the number is below normal, it is divided into two parts, one near Iceland and one on the Ural Mountains. Whether an actual relation with the sun spots is here evident can not

with certainty be decided to-day. The fact however, that the two sets of results, apart from the slight difference mentioned, are in their chief features so extraordinarily similar, is a new proof of the surpassing and decisive importance of the foregoing weather conditions "Witterungsvorgeschichte."

If we survey once again all these investigation results, then we must answer the question set forth at the beginning of this article as follows. That evidently, for variations in atmospheric circulation and for the whole formation of the weather, *the preceding condition of terrestrial weather is of more decisive importance than cosmic influences*. With this realization, a firm foundation has been secured to enable us to approach the *exploration of the problem of long-range forecasting*. In consideration of the problem of periodicity in the course of the weather, this realization means that possible periodic variations in solar radiation have a greater influence on terrestrial weather conditions only when they find a resonance in the complex system of the general circulation of the air, capable as it is of manifold oscillations in itself (8).

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TABLE 1.—*Correlation coefficients (multiplied with 100) between the monthly means of pressure difference, Ponta Delgada, Iceland, and the sun-spot numbers*

(Period 1874/1923)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
a. With the *simultaneous* monthly means of sunspot numbers	−16	+14	+1	−0	−40	+1	−3	−3	+18	+9	+14	−6
b. With the *increase* of the sunspot numbers from the *past* month	+5	−9	−20	+5	−29	−6	+8	−3	−14	+6	+10	+3
c. With the *increase* of the sunspot numbers up to the *next* month	+3	−8	−4	−8	+9	−16	−36	+11	−16	+17	−9	+0

The big coefficients are greater than twice the standard error.

TABLE 2.—*Correlation coefficients (multiplied with 100) of the simultaneous monthly means of pressure at stations of the subtropical belt of high pressure of the Southern Hemisphere*

(Period 1875/1924)

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
a. Argentina (2 stations) and Mauritius	+7	+21	−14	−1	−1	+14	−33	−25	+12	−14	+11	+14
b. Mauritius and Sydney (Australia)	+21	+5	+28	+18	+1	−2	+14	+10	+33	−5	+7	−2
c. Sydney (Australia) and Argentina (2 stations)	+8	+21	−19	−32	−20	−17	−32	−10	−17	−16	−9	+19

The big coefficients are greater than twice the standard error.

HIGH INTENSITY OF SOLAR RADIATION IN THE SPRING OF 1928

By P. GOTZ

[Die Naturwissenschaften, Heft 23, June 8, 1928, p. 474]

From experience it is known that in every year spring brings the highest value of total heat intensity of the sun. It is true that at that time the sun's rays have a path through the air strata longer than that traversed in summer, that on an average the ozone stratum is thicker,[1] and that in the first half of the year the atmosphere contains more floating particles (*Luftplankta*),[1] but at the same time it is in very large degree winter-dry. Measurements to date at Arosa (1,860 meters) show the maximum radiation in the year 1923, when the value reached was 1.6 calories per minute per square centimeter.

The spring of the present year brings especially high values. By reason of a rather large number of measurements not only with the Michelson actinometer, but also directly with the Abbot silver disk, the values under J' in the following table are trustworthy to within one-half of one per cent. In addition the table contains the time of observation, the corresponding elevation of the sun (h), the vapor pressure (e) and the relative humidity ($r.\ F.$).

Under J are entered the values of solar radiation theoretically possible when the atmosphere is entirely free from water vapor and dust and only the air molecules can cause depletion, that is, for a turbidity factor having

[1] Gotz, P. *Das Strahlungsklima von Arosa*. Berlin. 1926.

the value $T=1.00$ (according to Linke); here 1.932 calories per minute per square centimeter is taken as the solar constant and also for the purpose of calculating the turbidity factor T.

Solar radiation, Arosa, Switzerland

Date	Hour	Elevation of sun (h)	Vapor pressure, mm. (e)	Relative humidity, per cent ($r.\ F.$)	Radiation intensity, cal. min. cm^2. Value observed (J')	Radiation intensity, cal. min. cm^2. Value for T=1.00 (J)	Turbidity factor (T)
1928		°					
Feb. 21	11:01 a. m.	30.8	(1.6)	31	1.59	1.64	1.17
Feb. 21	11:32 a. m.	32.2			1.59	1.65	1.21
Mar. 17	12:04 p. m.	41.9	(1.4)	30	1.61	1.68	1.28
Mar. 18	11:44 a. m.	42.1	1.4	24	1.63	1.68	1.20
Mar. 19	12:03 p. m.	42.6	2.0	32	1.59	1.68	1.37

Until now the value of 1.63 calories was vouched for only at elevations above 3,000 meters. The turbidity of the air, especially in so far as relates to the dates given above, was very moderate; the normal March values of T are as follows: Arosa, 1.5; Davos, 1.8; Potsdam, 2.2; and Frankfort on the Main, 3.5. At 1.4 mm. the determinative water vapor content was very low; in good agreement with this was the value $e=1.5$ mm. at Arosa at the minimum of the turbidity factor, $T=1.13$, on the midwinter date of January 15, 1925. Even in case the values $J-J'$ for the forenoon of March 18, 1928, are extrapolated to vacuous space there results no necessity of a cause for the high radiation values outside of the high transmissiveness of the atmosphere.

Does a higher value of the solar constant play a rôle in the marked solar activity? Whatever may be the case, it will be interesting to await values for the spring of this year obtained at other points and especially Abbot's values for the solar constant.[2]—*Translated by W. W. Reed.*

GROWTH OF TREES IN THE FOREST OF DEAN IN RELATION TO RAINFALL

[Reprinted from Meteorological Magazine, March, 1928]

Mr. E. G. Burtt has kindly supplied several series of measurements of the annual rings of growth of trees in the Forest of Dean. The best and longest series was given by a yew, which grew on a southwest slope overlooking Lower Sondley. The tree was cut in the winter of 1922–23, and proved to be 200 years old. The individual measurements are given in Table 1, and smoothed values constructed by taking overlapping five yearly totals are shown in the uppermost curve of Figure 1. It will be seen that the tree grew very slowly at the beginning and end of its existence and more rapidly in middle age. There are four periods of most rapid growth; the first and most important occurred from about 1780 to 1800, with a maximum from 1786 to 1792, and the second reached its maximum in 1829 to 1830. The third maximum extended from about 1861 to 1878, but is not very striking; on the other hand, the fourth maximum, which comes at 1899 to 1900, is remarkably sharp and definite. It will be noticed that the lengths of the intervals between these maxima, about 40, 40, and 30 years respectively, give an average of 36–37 years, which is very near that assigned to the Brückner cycle.

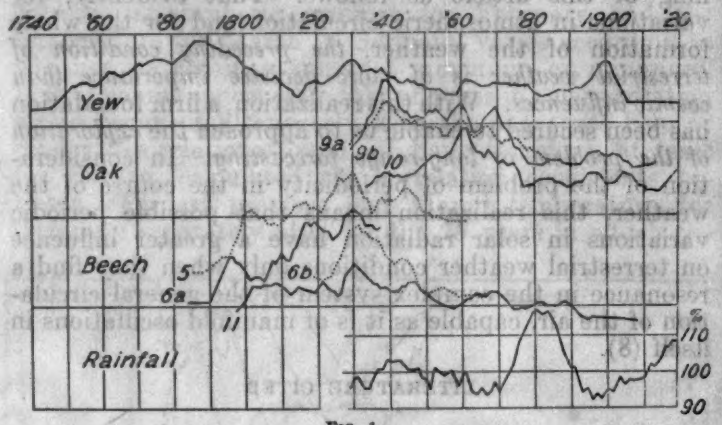

FIG. 1

Measurements of two oak trees are given, both of which grew on Staple Edge Hill and were cut about 1921. The individual measurements are not reproduced here, but the figures smoothed by forming five-yearly totals are shown in Figure 1. Curves 9A and 9B are from measurements taken at right angles on the same tree—an exceptionally well formed root—9A being along a line due west from the center and 9B along a line due north. An attempt had been made at some time to burn the stump, and the outer 40 mm., representing about 42 years' growth, were charred. It will be noticed that from 1830 to 1864 the tree grew somewhat more rapidly on the west than on the north side, but that from 1864 to 1883 this condition was reversed, growth being more rapid on the north side of the trunk. The curve labeled 10 represents the second oak tree, which showed no signs of burning. The two curves 9A and 9B are obviously closely related; No. 10 is fairly similar, but the pronounced maximum just before 1840 is barely represented, and the period of most rapid growth occurred instead about 1860. The most curious point is that these records of oak trees show very little similarity with that of the yew which grew only a short distance away. This is partly due to the much lesser age of the oaks, not one of which was 100 years old, so that the period of slow growth at the beginning of their existence coincides with the full maturity of the yew, and in fact with one of its periods of maximum. It is only when we examine the curves in detail that we can see points of resemblance, in particular the rapid increase of growth rate about 1860 and the general slow growth from 1880 to 1893. There is a distinct suggestion that the oaks responded more rapidly to changes of weather than the yew, for the curves 9 and 10 are far more irregular than the uppermost curve. The pronounced maximum at 1900 on the latter shows itself as a double maximum on both oak trees, and similarly the small minimum of 1865 on the curve for the yew becomes much more important in the oaks.

[2] Fortunately the Astrophysical Observatory of the Smithsonian Institution has already contributed the solar constant values for the dates in question to the Weather Bureau for publication on the Daily Weather Maps. The values are as follows:

Feb. 21	1.939 satisfactory minus.
Mar. 17	1.922 satisfactory minus.
Mar. 18	1.944 satisfactory minus.
Mar. 19	1.956 satisfactory minus.

—Ed.

TABLE 1.—*Growth of yew tree in millimeters*

Years	0	1	2	3	4	5	6	7	8	9
1740	----	----	----	1.0	1.0	1.0	1.0	1.0	2.0	2.0
1750	2.0	2.0	2.0	3.0	2.0	2.5	2.5	2.0	2.0	2.5
1760	2.5	3.5	3.5	3.0	2.0	2.5	3.0	3.0	4.0	3.0
1770	3.0	3.0	4.0	3.0	4.0	3.5	3.5	4.0	3.0	3.5
1780	3.5	3.0	4.0	4.5	4.0	4.5	5.0	4.5	5.0	4.0
1790	4.5	4.5	3.5	4.5	3.5	4.0	4.5	4.0	3.0	3.0
1800	3.0	3.0	3.5	2.5	2.5	2.0	3.0	2.5	2.5	2.5
1810	3.0	2.0	1.5	1.0	2.0	1.5	1.5	3.0	3.0	2.5
1820	2.0	2.0	2.0	3.0	3.0	2.5	3.0	3.5	4.0	4.0
1830	3.0	3.0	3.0	3.0	2.5	3.0	3.5	3.0	2.5	3.5
1840	2.0	2.0	3.0	2.0	2.5	2.0	2.5	2.5	2.0	2.0
1850	2.0	2.0	2.0	2.0	2.0	2.0	1.0	1.5	2.0	2.0
1860	2.5	3.0	3.0	1.5	2.0	2.0	2.5	2.5	2.0	2.0
1870	3.0	2.0	2.5	2.0	2.0	2.5	2.5	2.0	2.0	2.0
1880	2.0	1.5	1.5	1.5	2.0	2.0	2.0	2.0	2.0	2.0
1890	2.0	2.0	2.5	2.0	2.0	2.5	3.0	3.5	4.0	4.0
1900	3.5	3.0	3.0	----	----	----	----	----	----	----

Total growth 1823–1732, 8 mm., 1733–1742, 9 mm.
Total growth 1903–1912, 14 mm., 1913–1922, 14 mm.

Of the beech trees, Nos. 5 and 6 grew on the Blaize Bailey ridge and No. 11 grew near the yew tree; the dates of felling are not known, but were probably between 1900 and 1910. The two records 6A and 6B are from measurements along two lines at right angles on the same tree, but the actual directions are not specified. Since the dates of felling were not known exactly, it was necessary to fit the curves together from intrinsic evidence only. This was not difficult so long as only the three beech trees were considered; the correlation actually adopted seems to be the only possible one. When it came to fixing the age of the trees absolutely, by reference to the yew and oaks of which the dates of felling are known, it was a different matter, and the dating adopted in drawing Figure 1 is to be regarded as something of a guess. Like the oaks and the yew, the beech trees grew slowly at the beginning and end of their existence, while the response to changes of climate seems to have been more rapid than that of the yew, but perhaps not quite so rapid as that of the oaks.

For comparison between the rate of tree-growth and the amount of rainfall, Dr. J. Glasspoole has been good enough to calculate a series of rainfall values for the Forest of Dean extending from 1820 to 1920, expressed as a percentage of the normal for the 35 years 1881 to 1915. A comparison of these figures with the annual growths of the yew in Table 1 shows that there is little if any relation between the growth in any one year and the rainfall in that year. When we smooth the data over a number of years, there are some indications that heavy rainfall is inimical to the growth of the yew, but with the oak and the beech the relation is still indefinite. The rainfall data, smoothed by forming overlapping 10-year means, are shown in the lowest curve of Figure 1; following the model of the well-known American investigations into the relation between tree-growth and rainfall the curve has been shifted to the left, in order to compare the tree growth in any year with the rainfall during the previous 10 years. Thus the point where the rainfall curve crosses the vertical line for 1830 shows the rainfall of the years 1821 to 1830, which was 98 per cent of normal.

TABLE 2.—*Comparison of growth of yew tree with rainfall*

	1826–1835	1836–1845	1846–1855	1850–1865	1866–1875	1876–1885	1886–1895	1896–1905	1906–1915
Tree growth, mm..	32	26	21	20.5	23	19	21	28	(14)
	1820–1829	1830–1839	1840–1849	1850–1859	1860–1869	1870–1879	1880–1889	1890–1899	1900–1909
Rainfall, per cent...	95	104	98	96	98	114	102.5	92.5	98

The period of rather rapid growth of the yew about 1830 comes at a time when the rainfall curve is low, but the minimum from 1851 to 1859 follows the maximum of the rainfall curve by about 10 years. The poorly developed period of maximum growth from 1861 to 1870 fits in fairly well with the minimum of the same years on the rainfall curve, but the outstanding maximum shown by the latter about 1880 to 1883 is only represented by a slight minimum on the curve of tree-growth. On the other hand the pronounced maximum growth about 1900 agrees very well with the minimum on the rainfall curve. The opposition is also shown in Table 2, where the total growth of the yew in successive periods of 10 years is compared with the rainfall 6 years earlier. The most notable feature of this table is that, excluding the years 1906 to 1915, when the slow growth of the tree may be attributed to old age, the slowest growth, 19 millimeters in 1876 to 1885, corresponds with the decade 1870 to 1879, which was by far the rainiest, while the two periods of most rapid growth, 1826 to 1835 and 1896 to 1905, correspond with the two decades of least rainfall. There are no available records for the Forest of Dean previous to 1820, and a comparison of the growth of the yew from 1750 to 1820 with Doctor Glasspoole's figures for the whole of England, published in the *Meteorological Magazine* for February, failed to show any definite relationship. If the hypothesis that the yew grew best in dry weather is correct, we should infer that in the Forest of Dean the years 1803 to 1813 were rainy and the years 1780 to 1790 dry; it would be interesting to know if local non-instrumental records confirm or disprove this. The general results of the comparison are not very convincing, however, and do not make it probable that we shall ever be able to write the history of our rainfall from the rings of our trees, as has been done so successfully in the west of America, even if we can find trees of sufficient age.

WEATHER BUREAU STAFF MEETINGS, 1927 AND 1928

By EDGAR W. WOOLARD, Secretary

The regular biweekly meetings of the Scientific and Technical Staff of the Central Office of the United States Weather Bureau, initiated in the autumn of 1923, have been continued on the same plan as heretofore, during the winter of 1927 and 1928. Following is a list of the discussions (asterisks denote speakers not officially connected with the Weather Bureau); a report of the meetings of 1926 and 1927, with references to the reports of the meetings of previous seasons, will be found in the MONTHLY WEATHER REVIEW, 1927, **55**, 238.

October 4, 1927

H. C. Frankenfield. The Mississippi Flood of 1927.

October 19, 1927

H. H. Kimball. The meetings of the *International Geodetic and Geophysical Union* at Prague, and of the *International Commission for the Exploration of the Upper Air* at Leipzig.

November 2, 1927

**Col. E. Gold.* The work of the *International Commission for Synoptic Weather Information.*
**Th. Hesselberg.* On the Energy of Winds.

November 16, 1927

J. B. Kincer. The Weather of 1927.

November 30, 1927

O. L. Fassig. Tropical Air Currents.

December 21, 1927

C. F. Marvin. Improvements in weather service for aviation, agriculture, and commerce.

January 11, 1928

Messrs. *Marvin, Frankenfield, Humphreys.* Report of the meeting of the *American Association for the Advancement of Science* at Nashville.
E. W. Woolard. Report on the meeting of the *American Astronomical Society* at New Haven.

January 25, 1928

A. J. Henry. The winter anticyclone in the Great Basin.

February 8, 1928

Messrs. *Woolard, Humphreys, Weightman, Mitchell,* and *Henry.* Symposium on the cyclone.

March 7, 1928

C. L. Mitchell. Cyclones and anticyclones of the northern hemisphere, January–April, inclusive, 1925.

March 21, 1928

C. L. Mitchell. Forecasts for a week in advance based on northern hemisphere weather maps.

April 4, 1928

**H. L. Dryden.* Wind pressures on structures.

April 18, 1928

A. J. Henry. A review of Sir Napier Shaw's "Manual of Meteorology," Vol. II.

NOTES, ABSTRACTS, AND REVIEWS

A New Handbook of the World's Climates [1] (by Prof. Robert DeC. Ward).—Julius Hann's "Handbuch der Klimatologie" appeared in 1883 as a single-volume publication of a little less than 800 pages. It immediately took its place as the final and authoritative source of information on climate.

The second edition appeared 14 years later and a third edition, much enlarged, 14 years later, having over 1,500 pages and being contained in three instead of a single volume. The time has arrived when a new edition is demanded. Professor Ward remarks:

> It is a great satisfaction to be able to make here, at this meeting of the American Meteorological Society, the first public announcement, in the United States, of the preparation of a new handbook of climatology.
>
> This work is to be done under the editorial direction of Doctor W. Köppen, long well known as the meteorologist of the Deutsche Seewarte in Hamburg, a position from which, owing to advancing age, he retired some years ago. His title of admiralitätsrat fittingly recalls his valuable services in marine meteorology. Doctor Köppen is to-day the leading figure in the older school of European meteorologists. * * *
>
> With Köppen as general editor, the authoritative position of the new book is a foregone conclusion. Privatdozent Dr. R. Geiger, of the Bavarian Landeswetterwarte, is associated in editorial supervision.
>
> Some 25 or more authors are to contribute to the new *Handbuch.* Among these the following may be mentioned: Sir Gilbert Walker (India); Griffith Taylor (Australia and New Zealand); T. Okada (Japan and portions of the East Indies); A. Wegener (Greenland); Karl Sapper (Central America); C. Braak (southeastern Asia and portions of the East Indies); W. Meinardus (Antarctica); K. Knoch (South America); E. Alt (Europe); E. Kuhlbrodt (oceans); L. Berg, A. Kaminskij, and E. Rubinstein (Russia and Siberia); A. Wagner (free air); W. Köppen (geographical system of climate).

The plan is to have all the manuscript in the hands of the editor by December 1, 1930. As the various contributions are received from the different authors they will be at once set up in type, and will be issued as they come off the press. They will also be for sale separately. It is expected that these separate sections will appear at different times during the years 1929–33, the date set for the completion of the whole book being 1933. The size of the page will be large octavo, with about 600 words to a page, printed in fairly small but clear type.

Professor Ward himself has been asked to undertake the discussion of the climates of North America (including British North America and Mexico) and of the West Indies. The task is so great and his time so limited that he has requested Prof. Charles F. Brooks, of Clark University, to collaborate with him in the preparation of the manuscript. * * * Three hundred and thirty pages have been allotted for the discussion of North American climatology; of these 150 will be used for obligatory tables and 20 for charts. The text will be printed in English. One of the important features will be a new set of isothermal and isohyetal charts for

[1] Presented before the American Meteorological Society at its April meeting in Washington, D. C., and printed in full in Bulletin Am. Met. Soc. May, 1928, pp. 94-97.

North America as a whole. The lines are to be extended to include Central America and the West Indies.—*A. J. H.*

Hail damage in Iowa (by C. D. Reed).—Annual agricultural census enumerations by assessors give Iowa accurate comparable hail statistics such as are not available in any other State and probably not elsewhere in the world. The question on hail damage has been asked of each farmer in the State, beginning with the crops of 1923.

Five years of data are now available. The total damage reported is as follows:

1923	$2,319,506
1924	6,703,838
1925	7,975,691
1926	2,342,187
1927	5,064,717
Sum	24,405,939
5-year mean	4,881,188

Departure 1927+183,529=+0.4%.

There was considerable discussion during the crop season of 1927 as to the hail damage, compared with other years and with the usual. The above figures show that while the damage of 1927 was 0.4 per cent above the five-year average, in two other years out of five the damage was $1,750,000 to $3,000,000 greater. The damage in 1927 ranged from none in Davis and Dubuque Counties to $442,305 in Clinton County. The greatest damage in a single township was $155,150 in Eden Township, Clinton County. In 1925 the greatest county damage, $592,809, was in Keokuk, and the greatest township damage, $189,230, in English River in that county. In 1927, 664 townships, or 41 per cent of the total number, reported hail damage, while in 1925 the number was 749 or 46 per cent.

Evaporation at Kingston, Jamaica, 1927.—Mr. J. F. Brennan, Government meteorologist for Jamaica, publishes the total daily evaporation for Kingston during 1927. March of that year had a record of evaporating 7.85 inches of water with August a close second, having 7.80 inches. The least evaporation was in November with 3.54 inches.

A rain gauge exposed nearly alongside the evaporimeter registered 34.67 inches while the total yearly evaporation amounted to 69.07 inches, or about twice the measured rainfall.—*A. J. H.*

Sunspots in weather prediction (by Dr. Henry Norris Russell, Princeton Observatory. Reprinted, in part, from Scientific American, June, 1928).—* * * But the public always asks about the weather. Nqw an enormous amount of work has been done on the question of whether there is any connection between sun spots and the weather. Many competent men have handled it, discussing vast masses of statistics by reliable methods and the upshot of it all is that the influence of sun spots on the weather is exceedingly small.

In some parts of the world it is a little warmer on the average when spots are numerous, in others a little cooler. But "a little" means a fraction of a degree. The labor involved in detecting so minute a change is enormous. One must have observations covering at least four or five spot cycles, that is, more than 50 years, to be sure that one is not misled by chance happenings; and the mere job of taking averages is a big one. Small effects which only come clear if the much larger casual variations due to other causes when an average over many years can be taken, appear sometimes to exist. But they are so small in comparison with the other variations that their influence in determining the type of weather on different days, or even the average weather for a whole year, may safely be ignored.

The other causes are so much more influential that to depend on a study of sun spots to predict weather "is like watching an ant to predict which way an elephant will go." This trenchant phrase, which the writer heard recently from Professor Brown of Yale—as good an authority on such matters as could be found anywhere—summed up the whole situation.

These remarks do not apply to the serious attempts which are being made to investigate a possible connection between the small changes in the amounts of heat which the sun sends to earth (the solar constant) and weather conditions. In some regions where the course of the weather is unusually regular from month to month, such connection may exist, but even here little is known as yet, and it is well to be cautious in prophesying what may or may not happen in the future.

Meanwhile, if someone—usually someone with little mathematical or physical training—attempts to predict weather from sun spots, the rest of us need not take it very seriously. And if he offers to sell these predictions, we may well save our money.

Wind-bracing of tall buildings to be studied (reprinted from Engineering News-Record, April 19, 1928).—A study of data bearing on the problem of wind-bracing of tall buildings is to be carried out through the instrumentality of a research fellowship established at Ohio State University, Columbus, by the American Institute of Steel Construction. One phase of the study will be the observation of stresses in the members of the steel frame of the American Insurance Union tower in Columbus, whose columns during construction were equipped with gauge points to permit measurement of deformations under stress while the building is in service. It is expected that a committee of the Structural Division of the American Society of Civil Engineers will cooperate in studying and interpreting the data obtained through the proposed research work.

Rains improve Hawaii's crop outlook.—The heavy rainfall in all the Hawaiian Islands during the past month has filled reservoirs and irrigation ditches, making the agricultural outlook for 1928–29 crops unsuually good.—*Reprinted from Commerce Reports May 28, 1928.*

Indian monsoon.—In British India the season's monsoon set in last week and broke vigorously and generally as reported by Assistant Trade Commissioner W. L. Patterson in a cable from Calcutta June 15.—*Commerce Reports June 25, 1928.*

Weather in other countries (reprinted from Commerce Reports May 7, 1928).—*Dominican Republic:* * * * The drought continues; it has been regarded as the most severe in years. * * * *Jamaica:* Economic conditions in Jamaica continue favorable notwithstanding the fact that crops may be injured unless persistent drought is soon broken. * * * *Porto Rico:* The continuance of the drought, which shows no signs of breaking has caused serious damage to crops in general. * * *

May weather in the United States 50 years ago.—The weather of the first part of 1878 was unusually warm; with the beginning of May, however, the type changed to cooler rainy weather with heavy rains in the Plains States from the Dakotas to Texas. There were several destructive tornadoes and a number of severe thunderstorms. Light to heavy frost occurred about the middle of the month in the upper Lake region States, New England, New York, New Jersey, Pennsylvania, Maryland, and Virginia, and light snow was reported in the northern border States also in the mountains of Wyoming, Colorado, New Mexico, Utah, and Nevada. On the whole

there was great variety in the weather experienced in various parts of the country—*A. J. H.*

Meteorological summary for Chile, April, 1928 (by J. Bustos Navarrete, observatorio del Salto, Santiago Chile).—The circulation of the atmosphere was characterized by increasing activity; the paths of the depressions had a progressive movement toward the north and with this came the beginning of the rainy season in central Chile.

The depression of the 8th–9th affected conditions in southern and central regions and caused storms of wind and rain in the area from Chiloe to Coquimbo. The heaviest amounts, 4.30 to 5.50 inches, fell in the region between Curico and Talca. In all of that section of the cordillera there were heavy snowstorms which caused considerable damage. Between the 15th and 17th and again on the 18th–19th depressions crossed the southern region. In the first period the storms and rains extended to Talca and the excessive amount of 3.98 inches was recorded at Valdivia on the 16th; in the second period the rain area reached northward to Concepcion and there was another heavy 24-hour amount of 2.32 inches at Valdivia on the 19th. Depressions of minor importance affecting only the southern region, were charted on the following days: 3d–4th, 5th, 21st, and 27th

The important anticyclones were charted as follows: 1st–3d, in the region of Chiloe; 10th–14th, moving from the Juan Fernandez Islands through central Chile toward Argentina; 22d–25th, forming in the region of Chiloe and advancing toward northern Argentina; and, 30th, forming over southern Argentina.

At Santiago the total precipitation for the month was 1.21 inches, while at Valdivia it was 17.57 inches.—*Translated by W. W. R.*

Meteorological Summary for Brazil, April, 1928 (by Francisco de Souza, acting director Directoria de Meteorologia, Rio de Janeiro).—The depressions of the higher latitudes and that overlying the continent were about normal in activity.

The wind movement was lighter than in the preceding month; two storms of very moderate intensity passed over the extreme southern part of the country. The weather was rather unsettled, especially in the south, where precipitation was abundant. Temperatures were somewhat lower. Rainfall was extremely light, averaging 2.80 inches below normal in the northern region, but abundant in the central and southern regions, especially in the latter, where there was an average excess of 2.65 inches.

At some points in the north cotton and cereals were injured by pests or adverse meteorological conditions, but the general condition of the crops was not affected. Good yields of cereals, cotton, and cacao were obtained in the Amazonian region and in the central and southern States. Tobacco is being cut in the southern States. Harvesting of coffee has begun in the central and southern regions; yields are good.

At Rio de Janeiro the weather was fine on all except a few days. The mean cloudiness was slightly below normal and the duration of bright sunshine was 50 hours above the normal amount for the month. Mean maximum and mean minimum temperatures were above normal and there were 13 days on which the temperature exceeded 86° F. The prevailing winds were from the south quadrant; the mean velocity was 11.9 miles per hour and the extreme 44 miles per hour from the south-southeast during a storm in the early afternoon of the 25th.—*Translated by W. W. R.*

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RECENT ADDITIONS

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING MAY, 1928

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements, the reader is referred to the REVIEW for January, 1924, **52**: 42, January, 1925, **53**: 29, and July, 1925, **53**: 318.

Table 1 shows that solar radiation intensities were slightly below the normal values for May at Lincoln, Nebr., and close to normal at Washington, D. C., and Madison, Wis. At Washington an intensity of 1.46 gr. cal. per minute per cm.² measured at 10 a. m. of the 24th exceeds slightly the previous maximum for May at that station.

Table 2 shows that the total solar radiation received on a horizontal surface directly from the sun and diffusely from the sky was close to the May normal at Washington and decidedly above at Madison and Lincoln.

Skylight polarization measurements at Washington made on seven days give a mean of 54 per cent, with a maximum of 63 per cent on the 2d. At Madison measurements made on seven days give a mean of 58 per cent with a maximum of 68 per cent on the 12th. These are close to the corresponding average values for May for both stations.

TABLE 1.—*Solar radiation intensities during May, 1928*

[Gram-calories per minute per square centimeter of normal surface]

WASHINGTON, D. C.

Date	Sun's zenith distance										
	8a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
May 2	6.50			0.89	1.09	1.36	0.90	0.62	0.45		7.29
May 4	8.79		0.58	0.71	0.91	1.23	0.78	0.60	0.33		8.48
May 5	11.38		0.41	0.58	0.84	1.23					10.97
May 10	7.87	0.59	0.69	0.83	1.05	1.28					7.87
May 11	10.21						1.00	0.83			10.21
May 12	5.56						1.20	1.01	0.84		5.16
May 14	5.79	0.72	0.84	0.97	1.18	1.39	1.09	0.94			4.57
May 15	7.29			0.71	0.88						10.21
May 24	6.27				1.16	1.53					5.16
May 30	10.59				0.89	1.16					9.83
May 31	8.48				0.98	1.36	0.97	0.73			8.18
Means		(0.66)	0.63	0.78	1.00	1.32	0.99	0.79	0.54		
Departures		+0.02	−0.05	−0.04	+0.01	+0.04	±0.00	±0.00	−0.12		

TABLE 1.—*Solar radiation intensities during May, 1928*—Contd.

MADISON, WIS.

Date	Sun's zenith distance										
	8a. m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	[1] 1.0	2.0	3.0	4.0	5.0	e.
	mm.	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*mm.*
May 1	6.02				1.17	1.42					6.50
May 5	6.27				1.21	1.41					4.37
May 7	4.37				1.24						3.81
May 9	6.50				0.85	1.25					7.04
May 11	4.57				1.06	1.50					3.30
May 12	3.99				1.27	1.43					3.45
May 23	6.50				0.76	1.20					7.04
May 28	5.79					1.39					6.02
May 29	6.76				1.18	1.40					6.50
Means					1.09	1.38					
Departures					−0.02	+0.02					

LINCOLN, NEBR.

May 1	3.45			0.84	1.10	1.32					4.75
May 4	6.50						1.17				6.50
May 5	5.36		0.83	0.97	1.16						3.81
May 9	9.14	−0.61	0.72	0.87	1.06	1.32					9.14
May 19	8.81		0.81	0.97	1.17	1.42	1.09	0.86	0.74		6.27
May 21	5.41		0.93	1.10	1.25	1.43	1.20	0.97	0.82		5.16
May 22	6.76			0.73	1.00						6.02
May 23	8.81			0.44	0.64						8.43
May 25	7.87		0.72	0.81							6.27
May 29	8.81		0.75	0.90	1.15						6.76
May 30	10.21			0.92	1.10	1.30					9.14
Means		(0.61)	0.79	0.86	1.07	1.36	1.15	(0.92)	(0.78)		
Departures		−0.09	−0.02	−0.08	−0.06	−0.02	+0.04	+0.01	−0.01		

[1] Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning—	Average daily radiation					Average daily departure from normal		
	Washington	Madison	Lincoln	Chicago	New York	Washington	Madison	Lincoln
1928	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*	*cal.*
Apr. 29	563	462	514	409	385	+105	+11	+21
May 6	418	606	567	498	426	−31	+138	+92
May 13	459	414	433	319	356	−7	−60	−83
May 20	361	581	638	463	304	−116	+97	+89
May 27	553	531	528	447	411	+57	+49	+13
Excess or deficiency since first of year on June 2						−560	+2,737	+1,183

POSITIONS AND AREAS OF SUN SPOTS

[Communicated by Capt. C. S. Freeman, Superintendent U. S. Naval Observatory]
[Data furnished by Naval Observatory, in cooperation with Harvard, Yerkes, and Mount Wilson observatories]
[The differences of longitude are measured from central meridian, positive west. The north latitudes are plus. Areas are corrected for foreshortening and are expressed in millionths of sun's visible hemisphere. The total area, including spots and groups, is given for each day in the last column]

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1928	h. m.	°	°	°			
May 1 (Naval Observatory).	12 15	−82.0	183.4	−13.0		247	
		−73.5	191.9	−19.0	15		
		−64.0	201.4	−11.5		185	
		−57.5	207.9	−12.0		62	
		−29.5	235.9	−21.5		62	
		−29.0	236.4	+9.5		46	
		−28.5	236.9	+22.5		31	
		−19.0	246.4	+10.0		278	
		−2.0	263.4	−20.0		15	
		+7.5	272.9	−14.0	25		
		+18.5	283.9	−13.5	201		
		+28.5	293.9	−19.0		31	
		+81.5	346.9	−12.0	123		1,321
May 2 (Naval Observatory).	11 55	−81.0	171.4	−17.5	185		
		−72.0	180.4	−13.5		556	
		−60.0	192.4	−20.0	15		
		−50.5	201.9	−12.0		185	
		−42.0	210.4	−12.0		62	
		−17.5	234.9	−21.5		154	
		−15.0	237.4	+9.0		93	
		−7.0	245.4	+9.5		309	
		+12.0	264.4	−19.5		31	
		+20.5	272.9	−14.0		15	
		+31.0	283.4	−13.5	201		
		+42.0	294.4	−20.0		62	1,606
May 3 (Naval Observatory).	12 52	−68.0	170.6	−17.0	123		
		−57.0	181.6	−13.0		525	
		−37.5	201.1	−12.5		185	
		−27.5	211.1	−12.5	46		
		−4.5	234.1	−21.5		262	
		+2.0	240.6	+8.5		123	
		+10.5	249.1	+9.0		185	
		+45.5	284.1	−14.0	154		
		+60.0	298.6	−20.5	31		1,634
May 4 (Naval Observatory).	11 47	−55.5	170.5	−17.0		170	
		−44.5	181.5	−13.0		432	
		−24.0	202.0	−13.0		216	
		−18.0	208.0	−12.5	31		
		−14.5	211.5	−12.0	46		
		−9.0	217.0	−11.5		15	
		+7.5	233.5	−22.0		216	
		11.0	237.0	+9.0		31	
		+17.5	243.5	+8.5		62	
		+23.0	249.0	+9.0	216		
		+59.0	285.0	−14.5	185		
		+72.5	298.5	−21.0	31		1,651
May 5 (Naval Observatory).	11 37	−36.5	176.4	−15.0		340	
		−28.0	184.9	−12.5		309	
		−10.5	202.4	−13.0		278	
		−4.5	208.4	−13.0	31		
		−0.5	212.4	−12.5	46		
		+20.0	232.9	−21.5		201	
		+24.0	236.9	+9.0		31	
		+30.5	243.4	+9.0		46	
		+37.5	250.4	+9.0		139	
		+72.0	284.9	−13.5	139		1,560
May 6 (Harvard)	14 41	−18.0	180.0	−13.5		792	
		+7.0	205.0	−13.0		359	
		+34.5	232.5	−22.0		404	
		+47.0	245.0	+8.5		204	1,759
May 7 (Naval Observatory).	12 49	−74.0	111.8	+9.5	77		
		−44.0	141.8	+23.0		62	
		−14.0	171.8	−16.0		247	
		−7.5	178.3	−12.5		216	
		−0.5	185.3	−11.5		216	
		+15.5	201.3	−13.0	185		
		+22.0	207.8	−12.0		25	
		+27.5	213.3	−10.5		46	
		+45.5	231.3	−21.0		216	
		+51.5	237.3	+9.5		62	
		+58.0	243.8	+9.5		15	
		+64.0	249.8	+10.0	154		1,521
May 8 (Naval Observatory).	13 24	−60.0	112.2	+9.0	62		
		−55.5	116.7	+5.0	15		
		−29.0	143.2	+23.5		62	
		−28.0	144.2	+10.5		25	
		+1.5	173.7	−16.0		432	
		+8.0	180.2	−12.5		123	
		+14.5	186.7	−11.5		247	
		+29.0	201.2	−13.0		201	
		+38.0	210.2	−12.0		22	
		+59.0	231.2	−21.0		185	
		+66.0	238.2	+9.5	62		
		+78.5	250.7	+10.0	154		1,560

POSITION AND AREA OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1928—Continued	h. m.	°	°	°			
May 9 (Naval Observatory).	13 44	−46.5	112.3	+9.0	46		
		−41.0	117.8	+5.0	15		
		−17.0	141.8	+23.0		31	
		−9.5	149.3	−11.5		62	
		+14.5	173.3	−17.0		494	
		+21.5	180.3	−12.5		170	
		+29.5	188.3	−11.0	278		
		+42.0	200.8	−14.0		216	
		+50.5	209.3	−11.5		15	
		+69.0	227.8	−21.0		154	
		+80.0	238.8	+9.0		62	1,543
May 10 (Naval Observatory).	11 53	−34.0	112.6	+9.0	46		
		−28.5	118.1	+5.0	15		
		−2.5	144.1	+23.0		22	
		−0.5	146.1	−8.5		31	
		+3.5	150.1	−12.0		62	
		+31.0	177.6	−16.0		679	
		+42.0	188.6	−11.0	309		
		+54.5	201.1	−14.0		278	1,442
May 11 (Naval Observatory).	11 28	−21.0	112.6	+9.0	22		
		+18.5	152.1	−12.0		19	
		+42.0	175.6	−17.0		309	
		+57.5	191.1	−11.0		247	
		+66.0	199.6	−15.0	216		
		+71.0	204.6	−13.5	31		844
May 12 (Naval Observatory).	11 41	−8.0	112.3	+9.0	15		
		+32.0	152.3	−11.5		46	
		+51.0	171.3	−17.5		216	
		+60.0	180.3	−13.0		154	
		+69.5	189.8	−11.0		247	
		+78.5	198.8	−15.0		278	956
May 13 (Naval Observatory).	11 48	−80.0	27.0	−12.0		154	
		+46.0	153.0	−12.0		123	
		+63.5	170.5	−17.5		154	
		+72.5	179.5	−13.0		93	
		+85.0	192.0	−11.0		309	833
May 14 (Naval Observatory).	11 45	−67.0	26.8	−12.0		108	
		+59.5	153.3	−12.0		93	201
May 15 (Naval Observatory).	11 45	−81.0	359.6	−12.5	15		
		−52.5	28.1	−12.5		93	108
May 16 (Naval Observatory).	11 43	−65.5	1.0	−11.5	9		
		−42.5	24.0	−13.5		15	
		−38.5	28.0	−11.0		31	55
May 17 (Harvard)	13 56	−23.0	30.0	−12.5		17	17
May 18 (Naval Observatory).	11 48	−12.0	28.9	−11.0		6	6
May 19 (Naval Observatory).	11 29	−41.0	346.8	−10.0		15	
		−27.5	0.3	−14.0	6		21
May 20 (Naval Observatory).	11 33	−40.0	334.5	−20.5	6		6
May 21 (Naval Observatory).	11 53	−78.0	283.1	−15.5	108		
		−70.0	291.1	−19.5	46		
		−67.0	294.1	−20.0	25		179
May 22 (Naval Observatory).	12 48	−68.0	279.4	+12.5		93	
		−63.5	283.9	−16.0	93		
		−58.0	289.4	−20.0	19		
		−51.5	295.9	−20.0	25		230
May 23 (Naval Observatory).	12 42	−83.0	251.2	+9.0	154		
		−54.0	280.2	+12.5		46	
		−50.0	284.2	−16.5	77		
		−44.5	289.7	−19.0		31	
		−38.0	296.2	−20.0	6		314
May 24 (Naval Observatory).	13 11	−67.5	253.2	+9.0	154		
		−40.0	280.7	+12.5		77	
		−37.5	283.2	−17.0	77		
		−32.0	288.7	−18.0		62	
		−25.5	295.2	−20.5		15	385
May 25 (Harvard)	9 2	−57.5	252.5	+8.0	456		
		−29.5	280.5	+13.0		71	
		−26.0	284.0	−16.5	140		661
May 26 (Naval Observatory).	11 49	−70.0	225.0	−10.0		123	
		−42.5	252.5	+9.0	62		
		−11.0	284.0	−17.0	62		
		−5.0	290.0	−18.5		31	278
May 27 (Harvard)	11 14	−79.5	202.5	−7.0	519		
		−55.0	227.0	−6.5	134		
		−28.0	254.0	+10.0	69		
		+0.5	282.5	+13.0		62	
		+4.5	286.5	−18.0		239	

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1928—Continued							
May 28 (Naval Observatory).	11 36	−76.5	192.2	+9.0	.....	216	.....
		−69.0	199.7	−12.5	.....	617	.....
		−50.5	218.2	−11.0	.....	93	.....
		−41.5	227.2	−10.0	.....	62	.....
		−16.5	252.2	+9.0	46	.....	.....
		+12.5	281.2	+12.5	.....	185	.....
		+15.0	283.7	−17.0	77	.....	.....
		+21.0	289.7	−18.5	.....	123	1,419
May 29 (Naval Observatory).	12 13	−74.0	181.1	−15.5	.....	139	.....
		−68.0	187.1	+9.0	.....	77	.....
		−61.0	194.1	+9.0	185	.....	.....
		−56.0	199.1	−12.5	.....	741	.....
		−44.5	210.6	+10.0	.....	62	.....
		−38.0	217.1	−10.5	.....	46	.....
		−28.0	227.1	−10.0	.....	62	.....
		−2.5	252.6	+9.0	31	.....	.....
		+26.5	281.6	+12.0	.....	185	.....
		+29.0	284.1	−17.0	62	.....	.....
		+34.5	289.6	−19.0	.....	185	1,775

POSITIONS AND AREAS OF SUN SPOTS—Continued

Date	Eastern standard civil time	Heliographic			Area		Total area for each day
		Diff. long.	Longitude	Latitude	Spot	Group	
1928—Continued							
May 30 (Naval Observatory).	11 48	−60.5	181.6	−15.5	154	.....	.....
		−54.0	188.1	+9.0	.....	46	.....
		−48.0	194.1	+9.0	139	.....	.....
		−43.5	198.6	−12.5	.....	648	.....
		−30.0	212.1	+10.0	.....	123	.....
		−24.0	218.1	−10.0	.....	46	.....
		−15.5	226.6	−10.5	.....	77	.....
		+10.0	252.1	+9.0	25	.....	.....
		+37.5	279.6	+12.0	.....	93	.....
		+41.0	283.1	−17.0	62	.....	.....
		+43.5	285.6	+13.5	.....	62	.....
		+47.5	289.6	−19.0	.....	108	1,583
May 31 (Naval Observatory).	11 46	−47.0	181.9	−16.0	123	.....	.....
		−40.0	188.9	+8.5	.....	40	.....
		−34.5	194.4	+9.0	154	.....	.....
		−29.5	199.4	−13.0	.....	586	.....
		−20.0	208.9	+10.5	62	.....	.....
		−14.5	214.4	+8.5	.....	46	.....
		−9.0	219.9	−10.5	.....	31	.....
		−1.0	227.9	−10.5	.....	93	.....
		+23.0	251.9	+9.0	31	.....	.....
		+50.0	278.9	+12.0	.....	77	.....
		+55.0	283.9	−17.0	62	.....	.....
		+58.0	286.9	+13.0	.....	93	.....
		+63.0	291.9	−19.0	93	.....	1,491
Mean daily area for May.	.....	.....	.....	.....	.....	.....	912

AEROLOGICAL OBSERVATIONS

By L. T. SAMUELS

As indicated in Table 1 the average free-air temperatures for May were close to normal with the exception of Ellendale where moderately large positive departures occurred at all levels. Relative humidity departures were mostly negative, those at Ellendale being of considerable magnitude. Notwithstanding the supernormal temperatures at this station the vapor pressures averaged appreciably *below* normal. This is of significance in connection with the pronounced lack of precipitation during the month at Ellendale, the total being only 0.67 inch as compared to a normal of 2.80 inches.

Marked deficiencies in the free-air vapor pressures at Groesbeck likewise are of interest in connection with the dryness of the month, 63 per cent of the total rainfall at this station having fallen during one hour on the 20th. It will also be noted that, at this station, the free-air relative humidity averaged below normal as did the temperature, a relationship which might be expected to result in less than normal precipitation.

Of special interest in Table 2 are the northerly components which occurred in the resultant winds for the month at Ellendale as compared to the normal southerly component notwithstanding the fact that the temperature departures at this station were positive. At the other stations the resultant winds for the month as compared with their normals were in general agreement with the temperature departures, i. e., an excess of southerly components occurred with positive temperature departures and vice versa.

Easterly winds at high elevations in the middle latitudes indicate abnormal conditions and it is interesting therefore to note such a wind movement over the interior of the country between May 20 and 24. During this period a high pressure area settled down over the Great Plains States, its center moving slowly southward with practically no eastward component. With this relatively cold air over the Southern Plains States and western Gulf region winds over the Mississippi and Ohio Valleys were northerly in the lower levels and veered with altitude to northeasterly at 5,000 meters and higher. At Knoxville on the 22d the wind was due east from 1,000 to 4,500 meters and southeast to 8,000 meters. During this period a low pressure area formed over the Gulf States and with the lack of eastward movement in the general circulation this storm developed to considerable intensity and produced widespread precipitation over this region.

Special pilot balloon observations from a number of stations were dispatched to Pittsburgh in connection with the elimination balloon race of May 30. A severe thunderstorm enveloped most of the balloons shortly after the take-off and only 3 out of 14 escaped the storm and made safe landings in Virginia. Lightning struck three balloons causing the death of two men and the injury of several others. Exceptionally strong vertical currents were encountered by the balloons in this storm. A study of these conditions will be published at a later time.

TABLE 1.—*Free-air temperatures, relative humidities and vapor pressures during May, 1928*

TEMPERATURE (° C.)

Altitude M. S. L. (meters)	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)		Washington, D. C.[1] (7 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	20.0	+0.2	19.9	−0.5	15.0	+1.7	22.2	−0.4	16.3	−0.1	19.6	+1.6
250	19.9	+0.2	19.6	−0.5	.....	.....	21.3	−0.4	15.9	−0.2	16.8	+0.6
500	18.4	+0.5	17.6	−0.2	14.6	+1.7	19.5	−0.4	13.7	0.0	14.6	−0.4
750	17.0	+0.1	16.2	+0.1	13.4	+2.2	18.2	−0.3	12.3	+0.3	12.7	−0.7
1,000	16.1	+0.4	14.7	+0.1	11.8	+2.1	17.1	−0.3	10.8	+0.2	11.2	−0.7
1,250	15.4	+0.8	13.1	+0.1	10.1	+1.8	15.9	−0.5	9.5	+0.3	9.7	−0.8
1,500	14.3	+0.8	11.6	+0.1	8.5	+1.7	15.1	−0.4	8.0	+0.2	8.1	−1.0
2,000	11.6	+0.8	8.7	0.0	5.0	+1.2	12.7	−0.5	5.1	−0.2	5.4	−1.1
2,500	8.4	+0.4	6.0	0.0	2.1	+1.3	10.0	−0.6	2.7	−0.2	2.8	−1.1
3,000	5.1	+0.2	3.1	+0.1	−0.6	+1.4	6.7	−1.0	0.3	+0.1	0.4	−0.8
3,500	1.6	−0.1	0.1	+0.2	−3.2	+1.6	3.3	−1.4	−2.7	+0.1	−2.6	−1.4
4,000	−0.2	+1.1	−2.9	+0.3	−5.7	+2.2	−0.2	−1.8	−5.9	−0.1	.....	.....
4,500	−3.6	+0.7	−6.8	−0.1	.....	.....	−3.1	−1.7	−8.5	0.0	.....	.....
5,000	−5.8	+0.8	−10.3	−0.2	.....	.....	−5.9	−1.9	.....	.....	.....	.....

[1] Naval Air Station.

TABLE 1.—*Free-air temperatures, relative humidities and vapor pressures during May, 1928*—Continued

RELATIVE HUMIDITY (%)

Altitude M. S. L. (meters)	Broken Arrow, Okla. (233 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)		Washington, D. C.[1] (7 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	63	−7	65	+3	44	−16	67	−4	61	−2	56	−8
250	63	−7	65	+3	------	------	68	−4	61	−2	59	−4
500	61	−7	64	+1	43	−17	68	−5	60	−3	59	−1
750	61	−6	62	−1	39	−20	67	−5	58	−5	57	−1
1,000	59	−7	62	−1	39	−20	66	−3	57	−6	57	−1
1,250	55	−9	62	−1	40	−20	64	0	55	−7	57	−2
1,500	54	−7	63	0	41	−19	55	−4	56	−6	56	−4
2,000	54	−5	62	+1	43	−17	44	−6	57	−2	51	−9
2,500	56	0	61	+3	43	−16	38	−8	52	−2	50	−8
3,000	56	+2	59	+3	42	−15	39	−7	45	−5	52	−5
3,500	61	+7	54	0	40	−14	42	−3	47	−3	63	+2
4,000	59	+5	57	+4	39	−13	46	−1	51	+2	------	------
4,500	47	−5	62	+9	------	------	46	−2	59	+10	------	------
5,000	25	−27	59	+8	------	------	46	−9	------	------	------	------

TABLE 1.—*Free-air temperatures, relative humidities and vapor pressures during May, 1928*—Continued

VAPOR PRESSURE (*mb.*)

Altitude M. L. S. (meters)	Broken Arrow, Okla. (283 meters)		Due West, S. C. (217 meters)		Ellendale, N. Dak. (444 meters)		Groesbeck, Tex. (141 meters)		Royal Center, Ind. (225 meters)		Washington, D. C. (7 meters)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	14.87	−1.55	15.12	+0.07	7.19	−1.96	17.56	−2.03	11.24	−0.69	13.05	−0.25
250	14.72	−1.55	14.86	+0.06	------	------	16.87	−1.96	11.09	−0.67	11.60	−0.27
500	12.99	−1.33	12.94	−0.13	6.90	−2.00	15.07	−2.01	9.51	−0.62	10.01	−0.42
750	11.76	−1.14	11.57	−0.27	6.01	−1.85	13.53	−1.94	8.42	−0.64	8.47	−0.71
1,000	10.65	−1.15	10.62	−0.21	5.40	−1.73	12.40	−1.34	7.61	−0.63	7.59	−0.81
1,250	9.52	−1.05	9.56	−0.33	4.95	−1.60	11.01	−0.89	6.81	−0.61	6.89	−0.89
1,500	8.53	−0.76	8.87	−0.14	4.62	−1.36	9.05	−1.09	6.27	−0.40	6.12	−1.13
2,000	7.22	−0.22	7.15	0.00	3.88	−0.99	6.27	−1.14	5.21	−0.01	4.83	−1.30
2,500	6.10	+0.30	5.82	+0.17	3.13	−0.74	4.66	−1.10	3.85	0.00	4.07	−0.82
3,000	4.96	+0.37	4.41	+0.01	2.31	−0.71	3.87	−0.86	2.78	−0.02	3.73	−0.19
3,500	4.27	+0.53	3.26	−0.21	1.57	−0.75	3.24	−0.54	2.37	+0.19	3.81	+0.55
4,000	3.61	+0.57	2.86	+0.10	0.51	−1.23	2.89	−0.23	2.10	+0.48	------	------
4,500	2.41	+0.02	2.39	+0.23	------	------	2.65	−0.07	2.23	+0.83	------	------
5,000	1.33	−0.71	1.80	+0.11	------	------	2.45	−0.26	------	------	------	------

TABLE 2.—*Free-air resultant winds (m. p. s.) during May, 1928*

Altitude m. s. l. (meters)	Broken Arrow, Okla. (233 meters)				Due West, S. C. (217 meters)				Ellendale, N. Dak. (444 meters)				Groesbeck, Tex. (141 meters)				Royal Center, Ind. (225 meters)				Washington, D. C. (34 meters)			
	Mean		Normal		Mean		Normal		Mean		Normal		Mean		Normal		Mean		Normal		Mean		Normal	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
	°		°		°		°		°		°		°		°		°		°		°		°	
Surface	S. 22 E.	2.2	S. 8 E.	2.1	N. 70 W.	0.4	S. 83 W.	0.9	N. 11 E.	1.0	N. 8 E.	0.7	S. 18 W.	2.0	S. 5 E.	2.4	N. 61 W.	0.5	S. 76 W.	0.4	N. 34 W	0.8	N. 43 W.	0.6
250	S. 22 E.	2.2	S. 8 E.	2.2	N. 65 W.	0.5	S. 78 W.	1.0	------	------	------	------	S. 22 W.	2.6	S. 4 E.	3.0	N. 58 W.	0.9	S. 78 W.	0.5	N. 23 W.	2.7	N. 64 W.	1.8
500	S. 18 E.	2.6	S. 8	2.9	N. 87 W.	1.0	S. 84 W.	1.8	N. 7 E.	0.9	N. 11 E.	0.5	S. 25 W.	3.3	S. 1 W.	4.1	N. 81 W.	1.5	S. 61 W.	1.5	N. 19 W.	3.4	N. 68 W.	2.7
750	S. 16 E.	2.9	S. 5 W.	3.3	N. 80 W.	1.5	S. 83 W.	2.6	N. 62 W.	0.6	S. 45 E.	0.1	S. 33 W.	3.3	S. 9 W.	4.8	S. 88 W.	2.2	S. 71 W.	2.1	N. 14 W.	3.9	N. 66 W.	3.5
1,000	S. 4 W.	2.9	S. 21 W.	3.5	W.	2.0	S. 84 W.	3.1	N. 54 W.	1.0	S. 18 W.	0.3	S. 39 W.	3.5	S. 20 W.	5.1	N. 80 W.	3.4	S. 82 W.	2.8	N. 19 W.	4.8	N. 66 W.	4.1
1,250	S. 7 W.	3.1	S. 33 W.	3.8	S. 83 W.	2.5	S. 82 W.	4.1	N. 63 W.	1.4	S. 39 W.	0.8	S. 46 W.	3.2	S. 27 W.	5.3	N. 68 W.	5.1	N. 28 W.	3.6	------	------	------	------
1,500	S. 36 W.	2.8	S. 46 W.	4.0	N. 88 W.	2.7	S. 79 W.	5.1	N. 60 W.	2.2	S. 52 W.	1.1	S. 45 W.	3.1	S. 35 W.	4.8	N. 64 W.	5.6	W	4.0	N. 39 W.	5.5	N. 64 W.	5.5
2,000	S. 60 W.	3.2	S. 62 W.	4.5	W	5.4	S. 81 W.	6.6	N. 62 W.	2.8	S. 70 W.	2.4	S. 65 W.	2.9	S. 47 W.	4.7	N. 59 W.	6.2	N. 89 W.	6.2	N. 60 W.	6.6	N. 70 W.	6.8
2,500	S. 81 W.	3.8	S. 78 W.	5.5	S. 88 W.	7.7	S. 81 W.	8.8	N. 62 W.	5.8	S. 72 W.	3.9	S. 76 W.	3.3	S. 60 W.	4.9	N. 69 W.	8.4	N. 85 W.	6.6	N. 55 W.	8.5	N. 69 W.	7.2
3,000	S. 88 W.	4.3	W	6.0	S. 88 W.	11.4	S. 86 W.	9.2	N. 55 W.	9.4	S. 79 W.	5.5	S. 80 W.	4.4	S. 74 W.	5.8	N. 76 W.	9.6	N. 78 W.	8.4	N. 61 W.	10.2	N. 73 W.	7.6
3,500	N. 67 W.	4.3	N. 84 W.	7.2	S. 89 W.	10.0	N. 88 W.	10.0	N. 51 W.	9.4	S. 84 W.	6.3	S. 83 W.	4.3	S. 85 W.	7.0	N. 70 W.	10.8	N. 74 W.	8.7	N. 61 W.	10.6	N. 65 W.	7.6
4,000	N. 17 W.	6.9	N. 77 W.	7.7	N. 85 W.	10.0	N. 75 W.	11.3	N. 54 W.	9.2	N. 88 W.	8.1	N. 63 W.	7.3	N. 75 W.	9.7	N. 48 W.	9.1	N. 75 W.	8.6	------	------	------	------
4,500	N. 22 W.	10.8	N. 69 W.	8.8	N. 86 W.	9.6	N. 76 W.	10.0	------	------	------	------	N. 25 W.	9.3	N. 59 W.	9.1	N. 36 W.	10.7	N. 69 W.	10.9	------	------	------	------
5,000	N. 22 W.	11.4	N. 66 W.	6.5	W	5.0	N. 81 W.	11.5	------	------	------	------	N.	8.0	N. 89 W.	6.6	N. 15 W.	7.3	N. 71 W.	11.7	------	------	------	------

THE WEATHER IN THE UNITED STATES

THE WEATHER ELEMENTS

By P. C. DAY

GENERAL CONDITIONS

The month was notably free from extensive or widespread short-period variations, being almost continually warm in the western two-thirds and largely cool in the eastern third, with an important deficiency in precipitation over many districts. The weather on the whole was favorable for outdoor occupations but too cool for best crop development in the Eastern and Southeastern States.

PRESSURE AND WINDS

The pressure distribution was somewhat of the anticyclonic type, the area of highest pressure, slightly above 30 inches, being central over the far Northwest, a ridge extending southeastward to the Florida Peninsula, the averages diminishing slightly to the southwestward, but with little if any change northward toward the Canadian Provinces. This type of pressure was rather persistent during the first half of the month and no cyclones attended by precipitation of importance occurred during that period, though local precipitation, heavy in a few instances, occurred on the 4th and 5th from the southern plains northeastward to the Great Lakes, and again on the 7th and 8th along the Atlantic coast from northern Florida to southern New England, and local showers were quite frequent during the early part of the second decade from the southern Plateau eastward to the plains of Texas, Oklahoma, and Kansas.

By the 15th the general rainy conditions in the Southwest had developed into a considerable barometric depression over the middle plains, which advanced eastward into the central valleys and to the Great Lakes by the 17th. This was attended by showers with local heavy thunderstorms over the region covered and for the following few days showers occurred over wide areas from the Great Plains eastward.

About the 22d, conditions favoring thunderstorms overspread the central Gulf States and during the following few days some heavy rains occurred over the Southeastern States. These were quickly followed by a stormy condition central on the morning of the 25th near the lower Lakes, which, advancing southeastward over

the southern Appalachian Mountains and to the middle Atlantic coast, brought mostly light showers to much of this territory, the showers continuing until near the end of the month over a large portion of the Atlantic coast area.

In the more western portions the precipitation was mainly light and May as a whole was the driest month of its name in large areas of the far Northwest.

The anticyclones were mainly not strong and while unfavorable to the passage of important cyclones over the interior districts, yet of themselves produced no marked or sudden changes in temperature or other weather conditions.

The general distribution of the average pressure and its influence on the wind circulation are shown on Chart VI, and the departures from the normal for the month and changes as compared with the preceding month are shown on the insets of Charts II and III.

A table showing the more important wind or other damaging storms appears at the end of the section. This shows that they were confined principally to the area from the Great Plains eastward and were most numerous during the early part of the first decade, during the middle and latter parts of the second decade, and were reported in nearly all parts of the last decade.

Much damage from hail was reported and while a considerable number of tornadoes occurred they were mainly without great property damage or loss to human life.

TEMPERATURE

The day-to-day changes in temperature were mainly small, only in a few instances reaching as much as 20° in a period of 24 hours, and these were confined chiefly to the first week and to the districts from the lower Lakes and Ohio Valley eastward in connection with some unusually warm days about the 3d to 6th, quickly followed by the lowest temperatures of the month in portions of the area.

The first week as a whole was mainly subnormal as to temperature, though to a materially less degree than had been the case for a considerable period previously, and opportunity was afforded for vegetation to make considerable advancement already much delayed by unfavorable weather.

The second week continued rather cool over most southern and eastern districts, particularly so in the middle Atlantic coast area, but from the upper Mississippi Valley westward and over the Pacific coast this week was distinctly warm and favorable for vegetation.

From the 15th to 22d temperature conditions were mainly moderate, though it continued warmer than normal over the Pacific coast and Northwest, and was slightly warmer over many other districts.

The last week continued notably warm in the districts from the Rocky Mountains westward and was moderately warm in the Great Plains, but to the eastward cool weather continued, particularly in the Ohio Valley and near-by areas, the weekly averages ranging from 6° to 9° below the normal, and the growth and development of warm-weather crops was further retarded. In the far West this period was the warmest of the month, the weekly averages ranging up to 10° or 12° above the normal, and vegetation made rapid progress, particularly in the irrigated districts.

For the month as a whole there were wide differences in the temperature conditions. From the western Lake region and Mississippi River westward, except in southern Texas, temperatures for the month were above the normal, and decidedly so in the far Northwest, stations in Idaho and portions of near-by States having means in some cases higher than ever before recorded in May. At the same time average temperatures were as low as or lower than ever before recorded in May in some southeastern districts, notably at Jacksonville, Fla.

The highest temperatures of the month occurred early in the first decade from the Ohio Valley and Great Lakes eastward, but over the remaining districts they occurred mainly during the last few days. The highest reported was 116° in southern California, and the maximum readings were as high or higher than had occurred previously in May in portions of the far Northwest.

In the districts from the Rocky Mountains westward the lowest temperatures occurred mainly during the first few days, in the Gulf States about the 5th to 10th, extending over the more northern districts into the first half of the second decade. No unusually low temperatures were recorded and no serious frost damage resulted over important crop areas.

PRECIPITATION

As stated elsewhere, the month as a whole was decidedly lacking in the amount of precipitation that may usually be expected in May. Only 8 sections out of the total of 42 had amounts in excess of the normal, these embracing four in the Southeast and four in the southern Rocky Mountain and plateau regions. Elsewhere deficiencies were the rule, these being well marked from the middle Plains eastward and in the far Northwest. No important sections suffered greatly from this general lack of precipitation, however, as the soil was mainly well supplied with moisture during the early part from the general excess that occurred during April, while during the latter part precipitation was more favorably distributed though still usually less than normal. In portions of the far Northwest the month was the driest May of record.

Over most districts where drought existed at the end of April, relief came during May. This was notably the case in southern Florida where one of the severest droughts of record was partly relieved about the 21st to 23d and generally terminated by the end of the month.

SNOWFALL

No snow of importance fell save in the mountain districts of the West, notably in the elevated districts of Colorado where at a few points monthly amounts up to 30 inches were reported, while in the high Sierra of California amounts up to 18 inches occurred. On account of the continued warmth over the western mountains much of the snow at higher elevations was melted and the prospective late summer flow will be greatly reduced, particularly in the far Northwest.

RELATIVE HUMIDITY

The month was notably dry as measured by the percentages of relative humidity, which were below normal in all parts save locally in the middle Rocky Mountains and portions of the far Southwest and at a few points in the Appalachian Mountains and Northeast. It was notably dry on a number of days in the upper Mississippi Valley and portions of the Lake region, and the departures from normal were large over the Central Valleys, Lake region, and Northwest.

SPECIAL PHENOMENA

An unusually brilliant meteor was observed about midnight of the 22d–23d over an extensive area from southwestern Georgia to the coast of South Carolina. It seemingly exploded, causing vibrations sufficient to be mistaken for an earthquake.

SEVERE LOCAL STORMS, MAY, 1928

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Carlsbad, N. Mex.	2	3-4 p. m.	4 miles		$5,000	Heavy hail	Crops badly damaged	Official, U. S. Weather Bureau.
Clarks, Nebr.	2	5 p. m.	300		150,000	Tornado	Many buildings demolished; trees uprooted; telephone and telegraph poles broken; crops damaged.	Do.
Doniphan, Nebr.	2	5:30 p. m.	130		3,500	do	A number of farm buildings wrecked; path 11 miles long.	Do.
Bancroft, Nebr.	2	6:45 p. m.	880		50,000	do	Character of damage not reported	Do.
Buena Vista County, Iowa.	2	7:30 p. m.	1,760			do	do	Do.
Cherokee County, Iowa.	2	do			350,000	do	Extensive damage to farm property and overhead wire systems; 3 persons injured.	Tribune (Sioux City, Iowa).
Woodbury County, Iowa.	2	do			100,000	do	Character of damage not reported	Official, U. S. Weather Bureau.
Smith County, Kans.	2	8 p. m.			15,000	do	Houses unroofed; outbuildings and telephone lines blown down.	Do.
Iowa (northwestern) and Nebraska (northeastern).	2	P. m.				Winds, rain, and hail.	Considerable damage to crops, poles, and farm property.	Do.
Otis to Loving, N. Mex.	2				5,000	Thunderstorm and hail.	Character of damage not reported	Do.
Cypress, Fla.	6	1 p. m.	3 miles		5,000	Hail	Melon crop a total loss	Do.
Compass Lake, Fla.	6	2 p. m.	1,760			do	Many acres of orange trees damaged	Do.
Miccosukee, Fla., and vicinity.	6	3-6 p. m.	1-5 miles		23,000	do	Damage chiefly to crops	Do.
Monroe to Boston, Ga.	6	do			25,000	do	Damage chiefly to tobacco crop	Do.
Judson, Fla. (near)	6	9 p. m.	3-8 miles		50,000	do	Crops severely damaged	Do.
Redfield, S. Dak.	7	5:45 p. m.			500	Small tornado	Few small buildings blown down	Do.
Colorado, Tex.	13	8 p. m.	3,520			Hail	Crops almost a total loss over a path 15 miles long.	Do.
Harmon County, Okla.	14	do	5 miles		20,000	do	Crops injured; minor property damage	Do.
Carriere, Miss.	14	8:30 p. m.				Probably small tornado.	3 residences demolished	Do.
Cheneyville, La. (near)	14		1,760			Thundersquall	3 homes and several chimneys blown down; 2 persons injured.	Do.
Rockport to Tarkio (near) Mo.	15	3:30-4 p.m.	16-33		10,000	Tornado	Property damaged over path 16 miles long	Do.
White Cloud, Kans.	15	4:50 p. m.	do	1	2,000	do	1 home demolished, others damaged; several persons injured.	Do.
Rotan, Tex. (near)	15	5:30 p. m.	440		5,000	do	Buildings damaged; 3 persons injured; path 3 miles.	Do.
Raymore, Mo.	15	6:30 p. m.	10-33		8,000	do	Some destruction of property	Do.
Lutherville, Ark.	15				25,000	Tornado and hail.	Considerable property and crop damage	Do.
Pueblo, Colo. (south of)	16	1 p. m.				Tornado	No damage reported	Do.
Reed, Okla.	16	3:30 p. m.	440		20,500	do	A number of small dwellings and a schoolhouse demolished; all other buildings damaged; crops injured.	Do.
Erick, Okla.	16	4 p. m.			140,000	Wind	Extensive crop damage, minor injury to property.	Do.
Willow, Okla. (near)	16	do	6 miles		68,000	do	Damage chiefly to crops	Do.
Sayre, Okla.	16	5 p. m.	5 miles		125,000	Wind and hail	Severe property and crop damage; 1 person injured.	Do.
Olfton, Okla. (near)	16	10 p. m.	440	2	50,000	Wind	Oil derricks damaged; trees uprooted; crops injured; 23 persons hurt.	Do.
Kiowa County, Okla.	16					Heavy hail	Crops and other property extensively damaged	Do.
Justin, Tex.	17	5 p. m.	3 miles		50,000	Hail	Crops severely injured over path 30 miles long	Do.
Gainesville, Tex. (16 miles northeast of).	17	8 p. m.		1	7,500	Tornado	Crops ruined; buildings damaged; 4 persons injured.	Do.
Hall and Collingsworth Counties, Tex.	17				200,000	do	Property of all kinds damaged; 6 persons hurt; path 14 miles.	Do.
Iowa (northwestern)	17	P. m.				Hail	Damage chiefly to fruit	Do.
Sterling, Colo.	17					Hail and rain	Young crops injured; buildings, roads, etc., damaged.	Do.
Thackerville, Okla.	17	8-9 p. m.	1,760		100,000	Wind	Crops and property damaged over path 4 miles long; 4 persons injured.	Do.
Winters, Tex.	18	12:45 p. m.	5 miles		15,000	Hail	Considerable property damage; livestock injured.	Do.
Big Cabin, Okla. (near)	18	5-6 p. m.			10,000	do	Crops damaged	Do.
Rush and Barton Counties, Kans.	18	5:30-6 p.m.	1-10 miles.		75,000	do	Growing crops severely damaged	Do.
Amarillo, Tex.	18	7 p. m.	440		100,000	do	Auto tops, roofs, and windows ruined	Do.
Saline County, Kans.	18	6:30-7 p.m.	880-3,520		500,000	do	Damage principally to wheat	Do.
Gordonville, Tex.	18	9:30 p. m.	1,320		40,000	do	Crops damaged over path 10 miles long	Do.
Dimmitt and Plainview,	19	1 a. m.	4 miles		200,000	do	Roofs, windows, and crops severely damaged; path 45 miles.	Do.
Sidney, Nebr.	19	4 p. m.	3 miles			do	Gardens and crops injured over path 15 miles long.	Do.
Hyannis, Nebr.	19	4:30 p. m.	12 miles			do	Windows, roofs, and crops damaged; path 18 miles.	Do.
Dauphin, York, Cumberland and Perry Counties, Pa.	19					Electrical wind and hail.	Farm property damaged	Do.
Quay, N. Mex.	19			2	25,000	Thunderstorm and hail.	Orchards damaged	Do.
Williamson County, Tex.	20	A. m.				Hail	Crops destroyed	Do.
Jefferson County, Okla. (western).	20	5 p. m.	3,520			do	Heavy crop and property damage; path 25 miles	Do.
Ladessa, Okla. (near)	20	5:30 p. m.				do	Gardens entirely destroyed; fruit badly injured	Do.
Laredo, Tex. (near)	21	2:30 p. m.		3	75,000	Hail and wind	Heavy property damage; livestock killed; many persons injured.	Do.
Mountain Park, N. Mex.	21	7 p. m.	1,760		15,000	Heavy hail	Severe damage to apples and cherries	Do.
Dawson, Ga. (near)	22	11:45 a. m.			10,000	Hail	Cotton damaged	Do.
Snyder and Juniata Counties, Pa.	22	6-7 p. m.	1,760		15,000	Hail and wind	Damage chiefly to crops, barns and frail buildings.	Do.
Bradley, Ga. (near)	22				40,000	Hail	Heavy damage to peaches	Do.
Pickens and parts of adjacent counties, Ala.	22		3 miles		300,000	do	Chickens and livestock killed; many acres of crops ruined; 200 families left destitute; path 40 miles long.	Do.
Shellman, Ga. (near)	22					Small tornado	2 barns destroyed; several residences unroofed; trees, fruit, and tobacco injured.	Do.
Stewartsville, Ind. (near)	25	2:30 p. m.	50		7,000	do	1 dwelling, a barn, and a few outbuildings demolished; path 1 mile.	Do.
Lovett, Fla., to Nankin, Ga.	26	6 p. m.			2,000	Hail	Crops injured	Do.
Silcott, Wash. (near)	26	11:30 p. m.			4,500	do	Orchards badly beaten	Do.
Clark, Comanche and Kiowa Counties, Kans.	28	5:30 p. m.	3,520		250,000	do	Damage chiefly to growing crops	Do.

SEVERE LOCAL STORMS, MAY, 1928—Continued

Place	Date	Time	Width of path, yards	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Fairfield, Tex.	28	5:30 p. m.			1,000	Probably small tornado.	Minor damage to buildings	Official, U. S. Weather Bureau.
Booker, Tex.	28		1,320		40,000	Hail	Crops damaged; path 10 miles	Do.
Hondo, Tex.	29	4 a. m.	1,760		2,000	do	Crops badly damaged over short path	Do.
Kettle Falls, Wash. (near)	29	10:30 a. m.				do	Orchards and gardens considerably injured	Do.
Greensboro, Fla.	29	3 p. m.			5,800	do	Crops injured	Do.
Danbury, Nebr.	30	6 p. m.				Hail and wind	Partial to total loss of crops; some buildings damaged.	Do.
Red Willow and Frontier Counties, Nebr.	30	do	3 miles			do	Crops damaged from 85 to 100 per cent in places	Do.
Humphrey, Nebr. (near)	30					Small tornado	Crops and farm buildings damaged	Kansas City Times (Mo.).
Kansas City, Mo., and vicinity.	30	P. m.				Thunderstorm	Considerable damage to trees, buildings, etc.; several persons injured.	Official, U. S. Weather Bureau.
Raymondsville, Tex., and vicinity.	31	2:30 p. m.	3,520		500,000	Hail	Severe damage to buildings and crops over a path 15 miles long.	Do.
Cherokee, Okla. (near)	31	6 p. m.				do	Severe property and crop loss	Do.

RIVERS AND FLOODS

By R. E. SPENCER

Reports received too late for inclusion in the April REVIEW give the following additional figures pertaining to the floods of late April and early May in the Atlantic and West Gulf drainages:

Losses	Raleigh, N. C., district (rivers of North Carolina)	Mobile, Ala., district (Black Warrior and Tombigbee Rivers)
Tangible property (buildings, bridges, highways, etc.)	$2,500	$55,900
Matured crops		2,400
Prospective crops	5,000	105,500
Livestock and other movable property		19,600
Suspension of business	5,000	70,800
Savings accomplished through Weather Bureau flood warnings	15,000	255,700

In the Tombigbee-Black Warrior drainage, where lowlands were inundated to as much as 6 miles from the river banks in some localities, the flood proved of distinct value to lumber interests as a means of removing logs from swamp lands, the warnings affording sufficient time for preparations for the work. It is estimated that 14,000,000 feet of timber were floated out from the lowlands of the four counties nearest the mouth of the Tombigbee River.

The river service in Maine was reestablished recently under the supervision of the Weather Bureau Office at Portland, Me., after several years of inactivity. Owing to the rapidity of run-off and the comparative shortness of the streams in Maine, and to the consequence that rises generally occur while causative rains are still in progress, the river forecaster is required to estimate intensities of expected rainfalls. The method in use at Portland of course attempts nothing more definite than to predict these intensities as light, moderate, or heavy; but, with this general classification used as a key during a period of moderate flood conditions in Maine toward the end of May, the service proved quite equal to the demands made upon it. No damage occurred, and expressions of appreciation for the service—particularly from water power companies operating dams for the control of run-off—were numerous.

Other May rises in the Atlantic and East Gulf drainages were of little importance.

The consequences of the rises in the Yazoo Basin and the Atchafalaya and lower Mississippi Rivers were of no great importance. In the Tallahatchie and Yazoo Basins the combined overflow covered not more than 1,000 square miles, about one-fifth of which was under cultivation; but the land was replanted immediately upon the recession of the flood, so that the only actual loss was in seed and labor. In St. Martin Parish, La., over flow from the Atchafalaya also covered lowlands that had been planted to crops, but no estimate of the damage was received.

In the Shreveport, La., district, flood stages were passed in the Sulphur and Cypress Rivers, and damage estimated at $30,000 was done. Of this, $20,000 was to highways and railroad property, and $10,000 to crops.

On the Rio Grande no damage is reported at any point except in the vicinity of the city of Riogrande, Tex., where the rise, combined with concurrent heavy rainfall, damaged highways, culverts, and prospective and matured crops to the amount of about $75,000. As a result of Weather Bureau warnings, $5,000 worth of property was saved at Riogrande and extensive protective measures, reported to have saved many thousands of dollars, were taken at downstream points.

No damage is reported as a result of floods in the Denver, Colo., district; and the Columbia River rise which continued after the close of the month, will be discussed in the June number of the REVIEW.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
ATLANTIC DRAINAGE	*Feet*			*Feet*	
Susquehanna: Wilkes Barre, Pa.	20	1	2	20.0	May 1-2.
Potomac:					
Cumberland, Md.	8	(1)	1	10.4	May 1.
Harpers Ferry, W. Va.	18	2	2	18.9	May 2.
Roanoke: Weldon, N. C.	30	(1)	2	39.2	Apr. 29.
Tar: Rocky Mount, N. C.	9	2	2	9.6	May 2.
Neuse:					
Neuse, N. C.	15	(1)	3	19.3	Apr. 30.
Smithfield, N. C.	14	(1)	4	18.0	May 3.
Cape Fear:					
Fayetteville, N. C.	35	(1)	1	44.4	Apr. 29.
Elizabethtown, N. C.	22	(1)	3	31.2	May 1.
Peedee: Mars Bluff, S. C.	17	(1)	7	20.3	May 4.
		10	15	19.0	May 13.
		26	28	17.6	May 28.
Santee:					
Rimini, S. C.	12	(1)	24	15.4	Apr. 16.
		27	(1)	14.1	May 30.
Ferguson, S. C.	12	(1)	21	13.5	Apr. 28-29 and May 15.
		25	(1)	13.4	May 30.
Broad: Blairs, S. C.	15	9	9	15.3	May 9.
		24	24	15.0	May 24.
Saluda:					
Chappells, S. C.	14	8	10	17.4	May 9.
		24	25	17.2	May 25.
Three Mile Post, C. N. & L. R. R., S. C.	7	24	25	8.2	May 24.

Continued from last month. [1] Continued at end of month.

River and station	Flood stage	Above flood stages—dates From—	To—	Crest Stage	Date
ATLANTIC DRAINAGE—continued	*Feet*			*Feet*	
Altamaha:					
Charlotte, Ga.	15	(1)	8	21.2	Apr. 26.
Everett City, Ga.	10	(1)	15	12.5	May 2-4.
Ocmulgee:					
Abbeville, Ga.	11	(1)	4	14.9	Apr. 29.
Lumber City, Ga.	15	(1)	4	17.9	Apr. 25.
EAST GULF DRAINAGE					
Apalachicola:					
River Junction, Fla.	18	(1)	3	26.6	Apr. 27.
Blountstown, Fla.	20	(1)	5	24.6	Apr. 28.
Flint:					
Albany, Ga.	20	(1)	2	29.3	Apr. 24.
Bainbridge, Ga.	25	(1)	4	32.7	Apr. 27.
Alabama: Selma, Ala.	35	(1)	(2)	48.0	Apr. 27.
Etowah: Canton, Ga.	11	24	24	15.6	May 24.
Tombigbee: Lock 4, Demopolis, Ala.	39	(1)	10	61.2	May 1.
Pearl:					
Jackson, Miss.	20	(1)	8	29.8	Apr. 30.
Columbia, Miss.	18	(1)	3	22.9	Apr. 25.
West Pearl: Pearl River, La.	13	(1)	28	16.0	Apr. 28.
MISSISSIPPI DRAINAGE					
Stony Creek: Johnstown, Pa.	10	(1)	1	13.0	Apr. 30.
Monongahela:					
Lock 7, Greensboro, Pa.	30	1	1	33.3	May 1.
Lock 4, Pa.	31	1	1	32.5	Do.
Youghiogheny: Confluence, Pa.	10	(1)	1	11.0	Apr. 30.
Tippecanoe: Norway, Ind.	6	7	10	6.0	May 7-10
Big Pigeon: Newport, Tenn.	6	8	8	6.8	May 8.
Mississippi:					
Arkansas City, Ark.	48	2	11	49.2	May 6-7.
Vicksburg, Miss.	45	3	18	46.9	May 11.
Natchez, Miss.	46	16	16	46.0	May 16.
Baton Rouge, La.	35	16	16	35.0	Do.
Illinois: Beardstown, Ill.	14	(1)	1	16.0	Apr. 16-18.
St. Francis: St. Francis, Ark.	17	(1)	4	21.2	Apr. 27.
Arkansas: Yancopin, Ark.	20	(1)	18	36.7	May 3-4.
White:					
Georgetown, Ark.	22	(1)	9	28.2	Apr. 28-29.
DeValls Bluff, Ark.	24	(1)	10	27.9	Apr. 30-May 1.
Clarendon, Ark.	30	(1)	8	31.5	May 3.
Black:					
Corning, Ark.	11	(1)	7	13.5	Apr. 24-28.
		26	26	11.2	May 26.
Black Rock, Ark.	14	(1)	9	24.9	Apr. 22.
		23	23	14.3	May 23.
Cache: Patterson, Ark.	9	(1)	3	9.6	Apr. 27-29.
Yazoo: Yazoo City, Miss.	25	11	25	26.0	May 21.
Tallahatchie: Swan Lake, Miss.	25	(1)	19	30.6	May 2-4.
Sulphur: Ringo Crossing, Tex.	20	17	19	21.4	May 17.
Cypress: Jefferson, Tex.	18	22	24	19.8	May 22.
Atchafalaya: Melville, La.	37	15	19	37.2	May 15-17.
WEST GULF DRAINAGE					
Trinity: Dallas, Tex.	25	18	18	(4) 25.2	May 18.
Rio Grande:					
San Marcial, N. Mex.	3	3	17	4.0	May 5.
		25	25	3.1	May 25.
		28	(2)	3.4	May 31.
Riogrande, Tex.	21	14	14	23.8	May 14.
San Benito, Tex.	23	15	17	23.7	May 16.
Brownsville, Tex.	18	17	17	18.1	May 17.
PACIFIC DRAINAGE					
Colorado:					
Grand Junction, Colo.	11	29	(2)	11.5	May 31.
Parker, Ariz.	7	5	(2)	10.5	May 18, 19, 31.
Colorado, Roaring Fork: Carbondale, Colo.	5	26	(2)	6.1	May. 31.
Eagle: Eagle, Colo.	5	26	(2)	6.0	Do.
Gunnison:					
Sapinero, Colo.	19	29	(2)	20.1	Do.
Delta, Colo.	9	1	14	11.0	May 3.
		23	(2)	11.5	May 31.
Gunnison, North Fork: Paonia, Colo.	9	2	3	9.6	May 2.
		7	12	9.4	May 10.
Green: Elgin, Utah	12	13	17	12.5	May 15.
		28	(2)	13.0	May 31.
Columbia:					
Marcus, Wash.	24	17	(2)	34.2	May 30-31.
Umatilla, Oreg.	25	28	28	25.1	May 28.
The Dalles, Oreg.	40	27	(2)	42.1	May 29.
Vancouver, Wash.	15	12	(2)	25.4	May 31.
Kootenai: Bonners Ferry, Idaho	26	19	(2)	30.0	May 28.
Pend O'Reille: Newport, Wash.	16	17	(2)	24.0	May 31.
Clearwater: Kamiah, Idaho	14	8	13	14.9	May 9.
		20	27	15.7	May 26.
Willamette: Portland, Oreg.	15	12	(3)	24.4	May 31.

[1] Continued from last month.
[2] Continued at end of month.
[3] Below flood stage at 8 a. m., May 1.
[4] Estimated.

MEAN LAKE LEVELS DURING MAY, 1928

BY UNITED STATES LAKE SURVEY

[Detroit, Mich., June 4, 1928]

The following data are reported in the Notice to Mariners of the above date:

Data	Lakes [1] Superior	Michigan and Huron	Erie	Ontario
Mean level during May, 1928:	*Feet*	*Feet*	*Feet*	*Feet*
Above mean sea level at New York	602.16	579.93	572.07	246.61
Above or below—				
Mean stage of April, 1928	+0.31	+0.42	+0.29	+0.19
Mean stage of May, 1927	+0.28	+0.77	+0.11	+0.66
Average stage for May, last 10 years	+0.57	±0.00	−0.17	+0.42
Highest recorded May stage	−0.89	−3.59	−2.35	−2.34
Lowest recorded May stage	+1.98	+1.77	+0.90	+1.65
Average departure (since 1860) of the May level from the April level	+0.31	+0.30	+0.34	+0.34

[1] Lake St. Clair's level: In May, 1928, 574.55 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, MAY, 1928

By J. B. KINEER

General summary.—The first decade of May had more favorable weather than had previously prevailed and farming operations made better advance. Less rainfall in the Southeast promoted better germination and growth, and in the Atlantic area, the Ohio Valley, and the Lake region the warmer weather was welcome and more activity in farm work and crop growth was noted. During the first part of the second decade cool weather retarded germination and growth in most sections east of the Mississippi River, but soil moisture was mostly sufficient. To the westward favorable conditions for agricultural activity and crop growth were experienced, but during the latter part of the period there was a need of moisture reported from parts of the northern Great Plains and the Northwest. During the last decade warmer weather was needed generally over most areas east of the Mississippi River and some parts needed rain, although there was generally ample soil moisture. Over the western two-thirds of the country conditions were generally very favorable in most central and southern sections where there was a fairly good supply of soil moisture, but in northern sections a good, general rain was needed over a large area from the upper Mississippi Valley and northwestern Lake region westward to the Pacific Ocean.

Small grains.—The weather was fairly favorable during the first decade in the eastern winter-wheat belt with some slight advance of the remaining crop, while with the warmer weather there was also some improvement indicated in the upper Mississippi Valley. In the Great Plains and westward to the foothills of the Rocky Mountains timely rains and moderate temperatures were of material benefit. During the second decade there was further generous rain in the Southwest and western portions of the belt and soil moisture was generally ample over most western parts. In the eastern portion there was little change noted. During the last decade the weather continued generally favorable over the western portion and some improvement was noted in

the Ohio Valley, but it was not marked. In the far Northwest the unusually warm, dry weather was detrimental.

The first decade was nearly ideal in the spring-wheat belt and seeding had been nearly completed with favorable conditions for germination, except in some dry areas of South Dakota. The second decade was also mostly favorable for spring wheat, though some poor progress was reported in dry parts of the eastern belt. At the close of the month rain was generally needed throughout the belt, with the effect of the drought beginning to show in some sections, particularly in South Dakota and west-central Minnesota.

Oats were generally backward, but there was some improvement noted. Flax seeding had been retarded by dry soil in some central-northern sections, and growth was slow. Rice was doing well at the end of the month, while grain sorghums were coming up to good stands in the Great Plains.

Corn.—During the first decade corn planting made vigorous advance, under better weather conditions, in the middle Atlantic area and the central valley States. In Iowa progress of seeding was very good with planting ranging from well along to none accomplished. This work made generally good progress during the second decade with most of the crop in the heavy-producing sections, which was in marked contrast to last year. During the last decade corn made very good to excellent progress in the central trans-Mississippi States, where planting had been largely completed, but in the eastern Ohio Valley there was slow germination and growth, due to cool, rainy weather.

Cotton.—During the first decade the weather was rather too cool for best development of the cotton crop. Higher temperatures in the central and eastern portions of the belt were helpful and, for the most part, planting and replanting made good advance in the Carolinas and Georgia. In Texas less rain in the northeast and additional moisture in parts of the south and west made somewhat more favorable conditions, but growth was still slow, due to cool nights, and stands were generally poor to only fair. In Oklahoma the weather favored field operations, but planting progressed slowly in the east because of wet soil and the early seeded was reported as coming up to generally poor stands.

During the second decade better weather for the crop prevailed in most parts. In the Carolinas and Georgia moderate temperatures and showers favored germination of late-planted seed, and progress of the early planted was mostly fair to good. In Alabama and the States bordering on the Mississippi River progress was fair to very good. In Texas advance of early cotton was very good, but it was too wet in the northern portion of the State for favorable germination of late planted; the crop was generally late. In Oklahoma conditions were decidedly less favorable, with poor progress reported and planting and cultivation delayed.

During the last decade the weather was partly favorable. In the eastern half of the belt it was too cool, especially at night, but west of the Mississippi River conditions were generally favorable. In the Atlantic Coast States growth of cotton was slow to only fair, because of prevailing coolness, while in Alabama, Tennessee, and Mississippi warmer weather was needed, but progress was mostly fair. In Arkansas planting had been about completed with progress mostly very good, but in Louisiana advance was only fair. In Oklahoma the warmer, sunny weather made much better conditions and progress was good, chopping advanced, and stands were mostly fair to good. In Texas growth was also mostly good and favorable advance in chopping and cultivation was made.

Miscellaneous.—Meadows and pastures made fair to good progress in the South and East during the month, but slow growth was noted in the Northeast. There were some complaints of lack of moisture in the trans-Mississippi sections, and in the northern Great Plains there was also some unfavorable dryness reported. West of the Rocky Mountains moisture would have benefited rather generally, but in some parts there was excellent advance. Livestock continued to do well.

Potato planting was generally well along in northern sections at the close of the month with the crop doing well in most portions of the South. Truck crops were satisfactory, as a rule, and tobacco setting was well started in Kentucky. Cane made excellent growth in Louisiana and was well cultivated while sugar beet thinning was under way in some western parts. Citrus groves were in good condition in Florida and both citrus and deciduous fruits were doing well in California.

WEATHER OF THE ATLANTIC AND PACIFIC OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The weather conditions over the North Atlantic Ocean during May were in marked contrast to those that prevailed in April, when heavy weather was unusually prevalent. During May, however, the number of days with gales was considerably below the normal over practically the entire ocean. In the 5° square between the thirty-fifth and fortieth parallels and the seventieth and seventy-fifth meridians and that between the fortieth and forty-fifth parallels and the fortieth and forty-fifth meridians gales occurred on four days, while in no other square were they reported on more than three days. Over the greater part of the northern steamer lanes moderate weather was the rule.

Both the Azores HIGH and Icelandic LOW were comparatively inactive during the greater part of the month, with slight pressure gradients between these two centers of action.

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level, 8 a. m. (seventy-fifth meridian), North Atlantic Ocean, May, 1928*

Stations	Average pressure	Departure [1]	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Julianehaab, Greenland	30.11	(2)	30.42	17th	29.60	8th.
Belle Isle, Newfoundland	30.00	+0.06	30.40	24th	29.64	12th.[3]
Halifax, Nova Scotia	29.97	−0.03	30.18	18th	29.64	25th.
Nantucket	29.92	−0.09	30.30	14th [3]	29.62	25th.
Hatteras	29.92	−0.09	30.44	14th	29.62	24th.
Key West	29.96	−0.02	30.08	14th [3]	29.78	23d.[3]
New Orleans	29.98	+0.02	30.12	4th [3]	29.78	22d.
Cape Gracias, Honduras	29.88	+0.02	29.94	7th [3]	29.82	8th.
Turks Island	30.05	+0.05	30.12	16th [3]	29.92	5th.[3]
Bermuda	30.09	+0.01	30.32	18th	29.84	25th.
Horta, Azores	30.14	−0.11	30.32	19th	29.62	28th.
Lerwick, Shetland Islands	30.03	+0.23	30.40	31st	29.56	15th.
Valencia, Ireland	30.01	+0.06	30.31	13th	29.60	3d.
London	29.93	+0.01	30.28	26th	29.53	16th.[3]

[1] From normals shown on Hydrographic Office Pilot Chart, based on observations at Greenwich mean noon, or 7 a. m. seventy-fifth meridian.
[2] No normal available.
[3] And on other dates.

Fog was unusually prevalent during the month over the region between the fortieth and forty-fifth parallels, west of the forty-fifth meridian, where it was reported on from 15 to 24 days; it also occurred on 13 days along the American coast between Hatteras and New York and on from 3 to 5 days over the eastern section of the steamer lanes.

On the 2d and 3d a moderate disturbance of limited extent was central about 500 miles north of the Azores, with northerly to northwesterly gales in the western quadrants. Charts VIII to XI cover the period from the 4th to the 7th, inclusive, and show the progress of this LOW, as well as the development of a depression in mid-ocean and one off the east coast of Florida, the latter occurring on the 7th.

On the 8th and 9th this last disturbance was over the American coast between Hatteras and New York, in which region moderate to strong northeast gales prevailed.

On the 11th Father Point was near the center of a LOW that drifted slowly eastward and on the 14th was over eastern Nova Scotia. During this period moderate weather was the rule with a maximum wind force of 7, reported on the 13th and 14th.

On the 16th a LOW of slight intensity and extent was central near 42° N., 50° W., and on the 17th northerly gales occurred between the fifteenth meridian and the European coast.

On the 19th and 20th a moderate disturbance that moved but little and gradually filled in was central near 40° N., 45° W. From the 21st to 27th moderate weather was the rule over the greater part of the ocean, although during this period comparatively low pressure prevailed along the American coast from Key West to Halifax. There was also an area of low pressure over the eastern section of the steamer lanes that by the 28th had developed into a fairly severe disturbance, though of limited extent, central near 46° N., 35° W.

From the 29th to 31st low pressure continued over the Canadian Maritime Provinces, with moderate winds over the ocean as a whole.

OCEAN GALES AND STORMS, MAY, 1928

Vessel	Voyage		Position at time of lowest barometer		Gale began	Time of lowest barometer	Gale ended	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
	From—	To—	Latitude	Longitude									
NORTH ATLANTIC OCEAN			° ′	° ′				*Inches*					
Steel Seafarer, Am. S. S.	Algeria	New York	36 20 N.	8 36 W.	May 1	Noon, 1	May 1	29.67	NNW.	SE., 2	N.	N., 8	NNW.-N.
Waukegan, Am. S. S.	Havre	do	48 07 N.	23 18 W.	2	4 p., 2	3	29.49	WNW.	W., 6	NW.	NW., 8	S.-WNW.
Michigan, Fr. S. S.	Bordeaux	Tampa	41 18 N.	21 20 W.	4	8 a., 4	4	29.49	WNW.	WNW., 11	NW.	WNW., 11	Steady.
Jobshaven, Du. S. S.	Rotterdam	Wilmington, N. C.	41 08 N.	44 20 W.	4	11 a., 5	6	29.48	W.	W., 9	WNW.	—, 9	W.-WNW.
Coelleda, Am. S. S.	New York	Glasgow	42 39 N.	40 56 W.	6	8 a., 7	8	29.60	NW.	NW., 7	N.	NW., 8	NW.-N.
San Gil, Br. S. S.	Honduras	Boston	36 35 N.	73 25 W.	7	4 a., 8	9	29.71	NE.	NE., 10	NE.	NE., 10	Steady.
Ipswich, Am. S. S.	Canal Zone	Newark, N. J.	39 28 N.	73 50 W.	6	5 a., 9	9	29.70	NE.	NE., 8	NE.	NNE., 10	Do.
Es. Almirante, Am. S. S.	New York	New Orleans	35 00 N.	75 18 W.	12	—, 12	16	30.14	N.	N., 7	E.	ENE., 8	
Dannedaike, Am. S. S.	Baytown, Tex.	Rotterdam	40 30 N.	50 00 W.	15	3 a., 16	16	29.70	NNW.	SE., 8	SW.	—, 9	
Dania, Dan. S. S.	Copenhagen	Boston	58 35 N.	2 10 W.	16	11 p., 16	18	29.05	N.	N., 7	NNE.	NNE., 9	N.-NNE.
Modoc, U. S. S.	Halifax	Ice Patrol	42 52 N.	49 06 W.	18	6 p., 19	21	29.59	NE.	NNW., 6	NNW.	NW., 8	NE.-NNW.
Oilfield, Br. S. S.	New Orleans	Ghent	38 00 N.	51 20 W.	19	2 p., 19	20	29.72	NW.	NW., —	NNW.	—, 9	NW.-N.
Tynefield, Br. M. S.	Barrow	Baytown, Tex.	25 54 N.	77 39 W.	23	1 p., 23	23	29.70	NW.	NW., 8	NW.	NW., 8	W.-WNW.-NW
Kerhonkson, Am. S. S.	Liverpool	Boston	47 59 N.	27 28 W.	26	4 p., 27	29	29.36	WNW.	WNW., 8	NNW.	—, 8	WNW.-NNW.
City of Flint, Am. S. S.	Boston	London	42 55 N.	44 30 W.	28	1 p., 28	29	29.96	NNW.	NNW., 8	NNW.	—, 9	Steady.
Huron, Am. S. S.	New York	Dominica	37 12 N.	73 22 W.	28	2 p., 28	28	29.72	SSW.	SSW., 8	SSW.	SSW., 8	Do.
NORTH PACIFIC OCEAN													
Las Vegas, Am. S. S.	Yokohama	Portland	34 30 N.	138 55 E.	May 2	10 a., 2	May 2	29.58	NE.	NE. 11	NE.	NE., 11	Do.
Iwatesan Maru, Jap. S. S.	do	San Francisco.	37 40 N.	145 20 E.	2	Mdt., 2	3	29.49	NW.	NE.—	N.	NE., 9	N.-NE.
Ayaha Maru, Jap. S. S.	Grays Harbor	Osaka	50 00 N.	177 58 E.	4	Mdt., 4	5	29.00		SSW., 10	—	—	
Chincha, Am. S. S.	New York	West Coast	14 49 N.	95 26 W.	5	Mdt., 5	6		SW.	N., 8	N.	N., 8	SW.-W.-N.
Toba Maru, Jap. S. S.	Yokohama	San Francisco.	37 50 N.	145 30 E.	9	8 p., 9	10	29.76	S.	SW., 7	NNW.	SW., 8	3 pts.
West Cajoot, Am. S. S.	Hong Kong	do	44 12 N.	147 31 W.	12	11 a., 12	13	29.01	S.	S., 10	S.	S., 10	SSE.-S.
Erviken, Nor. S. S.	Vancouver	Osaka	50 51 N.	177 27 W.	13	Mdt., 13	14	29.21	WSW.	W., 10	WNW.	W., 10	WSW.-W.
Lubrico, Am. S. S.	San Francisco.	Honolulu	37 17 N.	123 52 W.	14	2 a., 15	15	29.80	NNW.	NNW., —	N.	NW., 10	NNW.-NW.
City of Victoria, Can. S. S.	Yokohama	San Francisco.	41 53 N.	165 16 E.	23	9 a., 23	24	29.20	SSE.	S., 7	W.	W., 9	SSE.-SW.
West O'Rowa, Am. S. S.	do	Portland	42 30 N.	155 00 E.	23	— 23	25	29.38	WNW.	WNW., 4	WNW.	WNW., 9	Steady.
Wray Castle, Br. S. S.	Colon	Honolulu	15 20 N.	107 16 W.	24	3 p., 25	27	29.77	S.	SW., 7	NNE.	NW., 8	Backing.
City of Victoria, Can. S. S.	Yokohama	San Francisco.	44 00 N.	161 10 W.	28	6 p., 29	30	28.80	SE.	SW., 8	W.	SW., 9	SW.-W.
West O'Rowa, Am. S. S.	do	Portland	51 00 N.	159 00 W.	30	—, 31	31	29.09	NE.	NE., 4	N.	N., 8	NE.-N.-NE.
SOUTH PACIFIC OCEAN													
Stanley, Am. S. S.	Balboa	Sydney	30 30 S.	176 12 E.	7	10 a., 7	7	29.59	WNW.	WNW.—	SSW.	NNW., 9	NNW.-SW.
Steel Trader, Am. S. S.	do	Melbourne	30 20 S.	169 56 E.	18	4 a., 19	19	29.77	W.	W., 8	S.	SW., 9	W.-WSW.
Leopold L. D., Fr. S. S.	Panama	Auckland	33 36 S.	177 23 W.	27	6 p., 27	27	29.39	ENE.	NW., 10	—	NW., 10	N.-NNW.
SOUTH ATLANTIC OCEAN													
Oria, Nor. S. S.	Montevideo	Las Palmas	29 50 S.	48 03 W.	2	5 p., 3	4	29.61	SE.	SE., 8	SE.	SE., 9	Steady.

NORTH PACIFIC OCEAN

By WILLIS E. HURD

May, usually a quiet month on the North Pacific, seems to have been quieter than normal this year, as only a few gales, mostly of a minor and local character, have been reported. In only four instances did they exceed force 9. Of these, a northeast gale, force 11, occurred during the prevalence of a cyclone south of Japan on the 2d; a south gale, force 10, was experienced on the 12th near 44° N., 148° W., in connection with a cyclone of moderate intensity centered slightly to the westward; a west gale, force 10, occurred on the 13th, south of the middle Aleutians, during an intensification of the LOW of that region, and a whole northwest gale occurred off the central California coast on the 14th, along the steep gradients existing between a strong North Pacific anticyclone on the one hand and a continental depression on the other.

Japanese weather maps indicate that a typhoon of considerable depth lay off the south coast of Honshu on the 11th and 12th, but no reports are yet at hand as to its gale severity. The typhoon apparently originated south of Guam near the first of the month. It touched the central Philippines on the 8th, then recurved, and by the 10th, with a minimum pressure of about 28.82 inches, lay southeast of the Nansei Islands, whence it moved toward Japan, skirting the lower coast and passing northeastward, with greatly diminished intensity.

Pressure over the western part of the ocean was unsettled, and numerous depressions from the continent caused disturbed weather in Asiatic waters.

The Aleutian cyclone, especially during the latter half of the month, was developed to almost winter strength over the western part of the Gulf of Alaska, with the average center still at Kodiak, and, as in the preceding two months, with pressure a quarter of an inch below the normal.

The North Pacific anticyclone exhibited fewer signs of disintegration than usual because of intruding cyclones, and persisted strongly throughout the month.

The following table gives pressure data for several island and coast stations in west longitudes:

TABLE 1.—*Averages, departures, and extremes of atmospheric pressure at sea level at indicated hours, North Pacific Ocean, May, 1928*

Stations	Average pressure	Departure from normal	Highest	Date	Lowest	Date
	Inches	*Inch*	*Inches*		*Inches*	
Dutch Harbor [1]	29.67	−0.25	30.26	10th	29.02	13th.
St. Paul [1 2]	29.76	−0.10	30.32	27th	28.88	5th.
Kodiak [1 2]	29.62	−0.25	30.24	12th	29.06	16th.
Midway Island [1 2]	30.14	+0.05	30.28	11th	29.94	30th.
Honolulu [3]	30.06	+0.01	30.15	28th	29.93	11th.
Juneau [3]	29.94	−0.05	30.44	12th	29.42	28th.
Tatoosh Island [3 4]	30.08	+0.04	30.37	11th	29.59	28th.
San Francisco [3 4]	29.97	−0.01	30.14	1st	29.80	14th.
San Diego [3 4]	29.93	0.00	30.05	19th	29.78	2d.

[1] P. m. observations only.
[2] For 30 days.
[3] A. m. and p. m. observations.
[4] Corrected to 24-hour mean.

At Honolulu the prevailing wind was from the east, the trades blowing about 90 per cent of the time. The maximum velocity was 27 m. p. h. from the east, on the 12th.

One tropical disturbance occurred in Mexican coast waters this month—the first to be reported in May for period 1912 to 1928. It was probably of a minor nature, its greatest reported barometric depth being 29.77 inches, on the 25th, in 15° 20′ N., 107° 16′ W., maximum wind-force 8, from the northwest. The disturbance was under observation of the British steamer *Wray Castle* from the 24th to the 27th. On the last date she was in 15° 44′ N., 112° 27′ W., wind still slowly backing, and pressure rising.

A heavy and fairly persistent blanket of fog overhung the ocean in central and upper east longitudes, from 6 to 12 days of the month being reported foggy in most sections between latitudes 40° and 50° N., longitudes 140° and 175° E. Isolated fog occurred over the eastern half of the ocean, the percentage in no locality being high. The northern and southern extremes of reported fog were St. Paul Island, in Bering Sea, and off the southern half of Lower California.

CLIMATOLOGICAL TABLES[1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation, by sections, May, 1928

Section	Temperature								Precipitation					
			Monthly extremes								Greatest monthly		Least monthly	
	Section average	Departure from the normal	Station	Highest	Date	Station	Lowest	Date	Section average	Departure from the normal	Station	Amount	Station	Amount
	° F.	° F.		° F.			° F.		In.	In.		In.		In.
Alabama	69.5	−1.8	Brewton	99	31	2 stations	38	[2]8	3.64	−0.33	Riverton	6.32	Alaga	0.28
Arizona	70.0	+2.5	Buckeye	111	25	Williams	20	4	0.46	+0.19	Alpine	2.30	17 stations	0.00
Arkansas	69.5	+0.5	Portland	98	10	Thornburg	34	8	3.60	−1.42	Mountain Home	7.35	Amity	0.99
California	64.6	+4.0	Greenland Ranch	116	27	Helm Creek	9	1	0.52	−0.58	Lake Sebrina	3.82	35 stations	0.00
Colorado	53.4	+1.8	Wray	103	1	Longs Peak	11	4	3.25	+1.47	Hawthorne	7.26	Nast	0.56
Florida	73.0	−2.5	Homestead	97	28	3 stations	40	9	3.66	−0.29	Miami	10.67	Cedar Keys	0.82
Georgia	69.3	−2.3	Americus	98	31	Tallapoosa	37	9	3.99	+0.49	Dahlonega	8.78	Americus	0.64
Idaho	58.4	+5.5	Kooskia	104	25	Seafoam	11	2	0.53	−1.13	Grays Lake	2.00	5 stations	0.00
Illinois	63.3	+0.7	Jacksonville	96	10	Mount Carroll	27	7	2.55	−1.45	Casey	6.24	Edwardsville	0.94
Indiana	61.0	−1.2	Hobart	94	3	Wheatfield	24	13	2.95	−1.06	Paoli	5.39	Moores Hill	1.39
Iowa	62.6	+2.5	4 stations	93	[2]9	Webster	26	12	2.47	−2.11	Red Oak	6.19	Albia	0.61
Kansas	64.9	+1.5	Anthony	101	31	Goodland	32	[2]3	3.53	−0.21	Deerfield	8.77	Bazaar	0.94
Kentucky	63.2	−2.4	Quicksand	94	3	Farmers	29	8	3.55	−0.42	Williamsburg	6.99	Maysville	0.94
Louisiana	72.7	−0.9	Dodson	98	30	4 stations	40	[2]7	4.03	−0.40	Angola	8.71	Crowley	1.06
Maryland-Delaware	60.5	−2.1	2 stations	96	5	Oakland, Md	23	13	2.45	−1.14	Rock Hall, Md	4.81	Hancock, Md	0.75
Michigan	54.0	+0.1	Bangor	92	3	2 stations	18	13	2.36	−0.78	Lansing	4.47	Frankfort	0.57
Minnesota	58.1	+3.8	Milan	99	9	Hallock	20	12	1.28	−1.79	Albert Lea	3.35	New London	T.
Mississippi	70.7	−0.9	Aberdeen	98	31	2 stations	37	[2]8	4.26	−0.26	Woodville	14.20	Meridian	1.15
Missouri	65.8	+1.2	Lamonte	95	30	Jackson	29	8	2.84	−1.86	Seligman	6.37	Edgerton	0.78
Montana	57.3	+5.9	2 stations	98	[2]23	Browning	9	1	0.67	−1.51	Adel	3.73	Melstone	0.02
Nebraska	62.2	+3.2	McCook	102	30	2 stations	28	[2]5	3.49	−0.06	Hayes Center	8.18	Bertrand	0.90
Nevada	61.8	+5.4	2 stations	106	[2]29	Rye Patch	15	3	0.23	−0.60	Sharp	1.15	2 stations	0.00
New England	53.2	−1.7	Pittsfield, Mass	88	6	2 stations	21	[2]8	3.31	−0.06	Gardiner, Me	7.44	Providence, R. I	1.18
New Jersey	58.0	−2.2	2 stations	93	5	Layton	27	10	2.23	−1.47	Atlantic City	3.49	Phillipsburg	1.26
New Mexico	60.0	+0.4	Cambray	102	[2]29	Selsor Ranch	19	[2]5	2.60	+1.47	Fort Sumner	7.24	Lindrith	0.69
New York	54.7	−1.1	2 stations	93	4	Allegany State Park	18	13	2.46	−1.08	Jeffersonville	5.54	Lockport	0.94
North Carolina	64.3	−2.2	Greenville	96	4	Mount Mitchell	24	8	4.76	+0.73	Mount Mitchell	9.13	Beaufort	1.54
North Dakota	58.2	+5.6	Berthold Agency	107	24	Eckman	16	12	1.15	−1.40	Richardson	3.34	Ashley	0.22
Ohio	59.1	−1.3	Middleport	93	4	4 stations	26	[2]8	1.77	−1.93	Napoleon	3.90	2 stations	0.68
Oklahoma	69.3	+1.4	Hobart	105	31	Goodwell	36	5	3.93	−0.47	Boise City	7.72	Meeker	1.57
Oregon	58.6	+4.8	Oakridge	102	24	2 stations	10	2	0.46	−1.32	Valsetz	2.65	2 stations	0.00
Pennsylvania	58.0	−1.5	Lancaster	95	4	2 stations	20	13	2.23	−1.76	York Haven	5.10	Erie	0.65
South Carolina	67.7	−3.2	6 stations	94	[2]18	Little Mountain	40	9	5.22	+1.65	Clemson College	8.87	Charleston	1.05
South Dakota	61.0	+5.1	Forestburg	104	9	Castlewood	23	12	1.53	−1.46	Vermillion	4.53	Eureka	0.11
Tennessee	65.4	−1.3	5 stations	91	[2]3	Rugby	31	9	4.92	+0.80	Gatlinburg	9.76	Lewisburg	2.06
Texas	73.1	0.0	Hebbronville	109	28	Miami	35	5	3.37	−0.20	Abilene	12.03	Beaumont	0.23
Utah	59.7	+4.0	Saint George	103	29	Great Basin Experiment Station (Alpine).	12	3	1.48	+0.21	Soldier Summit	6.11	Lucin	T.
Virginia	63.2	−1.4	2 stations	96	[2]4	2 stations	29	[2]13	2.63	−1.32	Marion	6.50	Lynchburg	0.66
Washington	58.3	+4.2	Wahluke	103	25	2 stations	20	[2]1	0.97	−1.15	Heather Meadows	5.28	Trinidad	0.00
West Virginia	58.9	−3.0	6 stations	94	[2]3	Bayard	22	[2]13	2.61	−1.44	Bayard	5.30	Upper Tract	0.55
Wisconsin	56.9	+2.2	New London	95	24	Prentice	19	12	2.09	−1.83	Sheboygan	3.74	Downing	0.84
Wyoming	53.9	+4.5	Basin	94	28	Dome Lake	6	4	1.94	−0.13	Saratoga	4.41	Basin	T.
Alaska (April)	26.8	+0.9	Hydaburg	69	26	Eagle	−34	2	1.37	−0.28	Latouche	17.60	Nome	T.
Hawaii	72.5	+0.6	2 stations	91	[2]5	Volcano Observatory	49	17	6.43	+0.45	Eke, Maui	46.00	3 stations	0.00
Porto Rico	77.2	0.0	Dorado	94	5	Lares	56	8	10.10	+3.54	Adjuntas	17.97	Ponce	3.94

[1] For description of tables and charts, see REVIEW.

[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1928*

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles								0–10	In.	In.
New England							53.3	−1.3										74	2.63	−0.5										6.3		
Eastport	76	67	85	29.84	29.92	−0.04	47.8	+0.1	70	17	54	35	15	41	28	44	40	79	2.06	−1.0	13	5,971	s.	38	ne.	24	2	12	17	7.5	0.0	0.0
Greenville, Me	1,070	6		28.77	29.95		49.5		77	18	60	24	8	39	45				4.63		17		se.				6	8	17		0.0	0.0
Portland, Me	103	82	117	29.83	29.95	−.02	50.6	−2.7	69	31	57	37	9	44	23	46	42	75	4.61	+1.2	14	5,343	e.	25	nw.	12	9	8	14	6.1	0.0	0.0
Concord	289	70	79	29.61	29.92	−.06	52.4	−1.9	81	17	63	29	9	42	43				2.61	−0.4	10	3,513	nw.	23	nw.	13	10	9	12	5.8	0.0	0.0
Burlington	403	11	48	29.48	29.92	−.05	54.0	−2.5	77	4	63	31	8	45	35				3.40	+0.6	19	5,645	s.	28	s.	5	4	11	16	6.9	0.0	0.0
Northfield	876	12	60	28.98	29.93	−.04	50.6	−2.2	77	17	62	24	14	40	45	47	41	69	3.27	+0.5	18	4,655	s.	22	s.	1	5	10	16	7.1	0.0	0.0
Boston	125	115	188	29.78	29.92	−.06	55.4	−1.7	74	30	63	41	14	48	24	49	43	68	3.08	−0.1	8	5,495	e.	20	nw.	12	8	11	12	6.3	0.0	0.0
Nantucket	12	14	90	29.89	29.90	−.09	52.1	−0.2	69	28	58	41	8	46	20	48	46	85	3.13	+0.5	15	9,501	sw.	36	ne.	7	5	13	13	6.5	0.0	0.0
Block Island	26	11	46	29.87	29.90	−.09	52.6	−0.2	67	30	58	42	9	47	20	48	45	80	1.40	−2.1	11	9,493	sw.	30	nw.	13	5	14	12	6.2	0.0	0.0
Providence	160	215	251	29.75	29.92	−.06	55.8	−2.7	79	17	64	40	9	47	30	49	42	67	1.18	−1.8	12	7,438	nw.	36	nw.	13	9	8	14	6.2	0.0	0.0
Hartford	150	122		29.74	29.92	−.06	57.4	−0.1	79	10	66	39	8	48	39				1.97	−1.6	10		s.				14	6	11	5.1	0.0	0.0
New Haven	106	74	153	29.81	29.92	−.07	57.4	−0.5	74	29	66	41	9	49	25	51	46	73	2.26	−1.4	12	5,834	ne.	27	n.	12	10	11	10	5.3	0.0	0.0
Middle Atlantic States							60.4	−1.6										68	2.58	−0.9										5.7		
Albany	97	102	115	29.81	29.91	−.07	58.0	−1.3	84	4	68	39	13	48	35	52	48	73	2.50	−0.4	11	4,410	s.	25	s.	27	10	12	9	5.2	0.0	0.0
Binghamton	871	10	84	29.00	29.93	−.05	56.0	−1.4	89	4	68	33	14	44	41				2.56	−0.5	8	3,536	nw.	24	w.	5	5	14	12	6.0	0.0	0.0
New York	314	414	454	29.58	29.92	−.07	58.4	−2.2	80	4	66	41	13	51	26	50	43	64	1.98	−1.3	12	8,633	nw.	42	n.	12	5	14	12	6.6	0.0	0.0
Harrisburg	374	94	104	29.54	29.93	−.05	60.9	−0.9	89	4	71	41	14	51	38	52	45	60	2.22	−1.4	10	4,140	nw.	33	sw.	5	6	8	17	6.7	0.0	0.0
Philadelphia	114	123	341	29.81	29.94	−.05	62.4	−0.5	90	5	71	43	9	54	34	54	49	68	2.19	−1.1	13	6,418	n.	31	n.	12	8	9	14	6.2	0.0	0.0
Reading	325	81	98	29.57	29.92		61.0		89	4	71	41	13	51	38	52	44	59	2.76	−0.6	10	4,183	se.	19	se.	5	12	8	11	5.3	0.0	0.0
Scranton	805	111	119	29.08	29.93	−.05	57.9	−1.5	89	4	69	37	25	47	40	50	42	60	2.63	−0.8	10	3,940	n.	28	sw.	5	6	13	12	6.2	0.0	0.0
Atlantic City	52	37	172	29.86	29.92	−.06	56.4	−1.7	73	31	62	42	13	51	22	52	48	77	3.49	+0.4	15	10,362	s.	45	ne.	7	8	14	9	5.5	0.0	0.0
Cape Henry	17	13	49				58.0	−0.6	73	31	66	39	13	50	26	53	50	81	1.35		10		s.				9	9	13		0.0	0.0
Sandy Hook	22	10	55	29.89	29.91		57.2		76	4	64	43	9	51	25	51	47	74	1.91		11	7,572	s.	37	sw.	1	8	11	12	6.0	0.0	0.0
Trenton	190	159	183	29.71	29.91		59.8		91	5	70	40	13	50	41	52	46	67	2.45	−1.1	12	6,280	nw.	32	w.	1	8	9	14	6.4	0.0	0.0
Baltimore	123	100	215	29.79	29.92	−.07	63.0	−1.4	87	4	72	44	9	54	31	55	49	63	3.09	−0.4	15	5,883	se.	30	nw.	12	7	12	12	6.0	0.0	0.0
Washington	112	62	85	29.80	29.92	−.06	63.1	−0.6	94	5	74	41	14	53	40	55	49	67	4.00	+0.3	15	3,620	s.	28	n.	28	9	13	9	5.3	0.0	0.0
Cape Henry	18	8	54	29.89	29.91		63.0		89	5	70	47	15	56	29	57	54	76	3.10	−0.5	9	8,270	sw.	45	ne.	8	9	12	10	5.4	0.0	0.0
Lynchburg	681	153	188	29.19	29.93	−.07	64.4	−2.9	95	4	77	39	13	52	45	56	50	62	0.66	−3.0	10	4,760	w.	30	ne.	8	12	13	6	4.7	0.0	0.0
Norfolk	91	170	205	29.83	29.93	−.07	64.8	−1.4	91	4	74	47	9	56	34	57	52	69	2.14	−1.7	8	8,301	s.	35	ne.	8	8	10	13	5.9	0.0	0.0
Richmond	144	11	52	29.78	29.93	−.06	64.0	−2.5	91	5	75	43	14	53	38	56	50	67	1.99	−1.8	10	4,752	sw.	24	ne.	8	12	10	9	5.1	0.0	0.0
Wytheville	2,304	49	55	27.60	29.94	−.05	58.4	−3.0	87	4	69	34	13	48	43	51	45	67	3.56	−0.1	15	3,855	w.	25	w.	1	11	9	11	5.0	0.0	0.0
South Atlantic States							67.9	−2.3										71	3.56	0.0										5.1		
Asheville	2,253	70	84	27.62	29.93	−.06	60.4	−2.2	86	4	71	38	13	50	38	52	47	69	5.53	+1.9	15	4,561	nw.	25	nw.	25	14	9	8	4.5	0.0	0.0
Charlotte	779	55	62	29.11	29.94	−.05	67.2	−1.7	92	4	78	43	8	56	34	58	53	68	4.05	+0.4	16	3,064	sw.	19	ne.	7	8	13	10	5.4	0.0	0.0
Hatteras	11	11	50	29.91	29.91	−.10	65.4	−3.3	82	29	71	49	25	60	25	61	59	80	2.34	−1.4	14	9,152	sw.	38	ne.	8	11	11	9	5.0	0.0	0.0
Raleigh	376	103	110	29.53	29.93	−.06	66.2	−2.3	91	4	77	43	9	56	34	60	56	76	4.24	−0.6	12	5,990	sw.	23	ne.	7	9	13	9	5.5	0.0	0.0
Wilmington	78	81	91	29.86	29.94	−.07	67.8	−3.0	89	11	77	46	8	59	31	61	57	76	3.18	−0.3	12	4,818	sw.	20	sw.	26	12	11	8	5.0	0.0	0.0
Charleston	48	11	92	29.89	29.94	−.07	71.0	−1.7	89	29	78	49	9	64	27	64	60	75	1.05	−2.0	9	7,395	sw.	30	e.	6	10	14	7	5.1	0.0	0.0
Columbia, S. C	351	41	57	29.56	29.94	−.06	69.3	−2.6	91	4	80	46	8	59	33	60	54	66	5.33	−2.1	11	3,890	sw.	26	nw.	19	10	10	11	5.3	0.0	0.0
Due West	711	10	55	29.21	29.98		66.6		89	19	77	45	9	56	34				6.42		11	5,787	sw.	36	ne.	7	14	6	11	4.9	0.0	0.0
Greenville, S. C	1,039	139	146	28.86	29.94		66.8	−0.4	87	11	77	44	7	57	29	57	52	65	4.47		13	5,780	sw.	31	ne.	6	8	12	11	5.5	0.0	0.0
Augusta	182	62	77	29.74	29.93	−.06	70.4	−2.0	92	11	81	47	8	60	38	61	56	65	6.37	+3.3	9	3,919	nw.	22	w.	27	11	10	10	5.2	0.0	0.0
Savannah	65	150	194	29.88	29.95	−.05	70.6	−2.8	90	19	80	48	8	62	28	63	59	72	1.23	−1.8	4	8,035	w.	29	nw.	7	10	11	10	5.1	0.0	0.0
Jacksonville	43	209	245	29.91	29.96	−.04	71.6	−3.4	89	12	79	48	9	64	25	64	60	73	2.33	−1.7	6	8,006	sw.	29	e.	14	10	11	10	5.2	0.0	0.0
Florida Peninsula							75.5	−1.8										72	4.36	+0.6										4.1		
Key West	22	10	64	29.93	29.95	−.02	77.9	−1.2	88	29	83	68	11	73	15	70	67	72	1.50	−2.0	6	7,521	e.	39	sw.	23	19	8	4	3.1	0.0	0.0
Miami	25	71	79	29.95	29.98		74.1	−2.3	89	31	81	57	9	67	22	68	65	71	10.67	+4.2	9	7,473	e.	31	s.	22	12	12	7	4.3	0.0	0.0
Tampa	35	79	87	29.93	29.96	−.03	74.4	−1.9	89	31	83	52	9	66	26	67	63	72	2.42	−0.5	5	4,474	sw.	19	sw.	22	15	9	7	4.3	0.0	0.0
Titusville	44	5		29.91	29.96		72.8		94	29	82	51	8	62	33				4.16		4		sw.				13	10	8	4.7	0.0	0.0
East Gulf States							70.6	−1.9										69	3.43	−0.3										4.6		
Atlanta	1,173	190	216	28.74	29.96	−.03	67.4	−2.5	86	11	76	44	9	59	31	57	50	62	5.97	+2.5	11	6,915	nw.	26	nw.	1	12	6	13	5.2	0.0	0.0
Macon	370	78	87	29.56	29.95	−.04	69.3	−3.0	89	11	80	43	9	58	37	61	56	67	3.43	+0.6	11	4,005	sw.	22	nw.	6	11	8	12	5.1	0.0	0.0
Thomasville	273	49	58	29.66	29.95	−.04	71.6	−2.4	92	31	82	44	9	62	33	63	58	69	2.08	−1.9	9	3,395	sw.	19	nw.	13	8	9	14	6.0	0.0	0.0
Apalachicola	36	42	49	29.92	29.96		72.0		85	31	79	53	8	65	22	66	64	78	2.31		6	5,399	sw.	26	e.	14	19	6	6	3.5	0.0	0.0
Pensacola	56	149	185	29.90	29.96	−.03	72.0	−1.9	84	31	77	52	8	67	20	66	63	77	3.35	0.0	5	9,042	sw.	37	nw.	20	8	14	9	5.5	0.0	0.0
Anniston	741	9	57	29.19	29.98	−.01	67.0	−1.4	88	11	79	40	9	55	41				3.01	−0.1	12	3,212	nw.	16	se.	14	12	11	8	4.3	0.0	0.0
Birmingham	700	11	48	29.21	29.97	−.01	68.8	−2.3	88	31	80	46	9	58	35	60	54	66	3.84	+0.8	10	4,296	n.	22	se.	15	13	8	10	4.7	0.0	0.0
Mobile	57	125	161	29.90	29.96	−.03	72.6	−1.8	88	12	81	51	8	64	26	66	62	76	3.57	−0.8	9	6,843	sw.	28	se.	15	12	16	3	3.9	0.0	0.0
Montgomery	223	100	112	29.71	29.96	−.03	71.2	−2.2	90	31	81	49	9	62	32	62	56	64	2.60	−1.2	10	4,516	sw.	25	w.	19	11	12	8	5.2	0.0	0.0
Corinth	469	6					69.0		88	11	80	44	9	58	38				6.54		12		s.				9	19	3		0.0	0.0
Meridian	375	87	95	29.56	29.95	−.03	69.9	−1.4	92	31	81	46	9	59	35	61	56	66	1.15	−2.8	10	3,829	sw.	24	sw.	22	16	8	7	4.0	0.0	0.0
Vicksburg	247	65	73	29.70	29.98	+.01	71.6	−1.3	90	31	80	53	8	63	27	63	59	69	2.29	−2.0	7	4,321	se.	20	se.	15	15	9	7	4.2	0.0	0.0
New Orleans	53	76	84	29.91	29.96	−.01	75.0	−0.4	91	30	83	61	8	67	23	67	62	70	6.48	+1.9	5	4,299	se.	20	n.	7	14	14	3	3.9	0.0	0.0
West Gulf States							73.3	−0.1										68	3.06	−0.9										4.1		
Shreveport	249	77	93	29.69	29.95	.00	73.8	+0.2	95	27	84	53	6	64	29	64	59	65	2.57	−1.6	6	4,160	s.	20	se.	14	15	13	3	3.7	0.0	0.0
Bentonville	1,303	11	44	28.59	29.94	+.01	66.2	−0.2	88	30	77	43	5	55	37				6.62		11		n.		se.		24	3	4		0.0	0.0
Fort Smith	457	79	94	29.46	29.93	.00	70.6	+1.0	93	30	81	52	5	60	31	61	55	64	5.43	+0.6	9	5,209	e.	24	nw.	17	14	10	7	4.1	0.0	0.0
Little Rock	357	136	144	29.57	29.94	−.01	70.3	0.0	89	30	80	51	8	60	29	61	55	63	3.86	−1.2	8	5,790	s.	28	nw.	19	15	8	8	4.6	0.0	0.0
Austin	605	136	148	29.29	29.92		74.1	−0.5	97	27	85	51	7	63	30	65	60	67	2.70	−1.9	5	5,672	se.	31	n.	21	12	11	8	4.8	0.0	0.0
Brownsville	57	53	61	29.84	29.90		76.7	−1.9	96	26	85	55	7	69	29	68	65	76	6.48	+4.2	8	5,594	se.	19	n.	6	15	11	5	3.8	0.0	0.0
Corpus Christi	20	11	73	29.91	29.93	+.03	75.1	−1.1	97	26	82	58	7	69	30	69	66	77	2.00	−0.8	6	8,544	se.	34	ne.	13	10	7	14	5.5	0.0	0.0
Dallas	512	220	227	29.39	29.93		73.4		99	27	84	49	5	63	28				2.02		9	8,656	se.	35	nw.	20	14	13	4	3.9	0.0	0.0
Fort Worth	670	106	114	29.21	29.91	.00	74.2	+1.9	103	27	86	51	6	63	35	64	58	62	3.77	−0.6	9	6,561	s.	35	nw.	20	12	12	7	4.8	0.0	0.0
Galveston	54	106	114	29.91	29.97	+.03	74.4	−0.4	89	26	79	61	5	70	19	68	65	79	1.54	−1.9	5	7,690	s.	33	s.	14	16	13	2	3.1	0.0	0.0
Groesbeck	461	11	56	29.46	29.93		73.8		98	27	85	51	6	62	37				2.73		7	7,567	s.	26	se.	3	13	13	5	4.2	0.0	0.0
Houston	138	292	314	29.82	29.96		75.2	−0.3	98	27	84	54	6	66	26				2.14	−2.0	7	8,324	se.	32	nw.	22	13	17	1	3.5	0.0	0.0
Palestine	510	64	72	29.42	29.95	+.02	73.6	+0.9	97	27	84	51	5	63	33	64	58	65	0.58	−4.0	7	5,067	s.	22	se.	3	17	10	4	3.3	0.0	0.0
Port Arthur	34	58	66	29.92	29.96		75.0		94	26	83	54	6	67	26				0.45		5	5,935	s.	26	s.	14	20	9	2	2.8	0.0	0.0
San Antonio	603	119	132	29.20	29.92	+.02	74.7	−0.4	97	27	85	54	6	64	33	64	58	63	3.90	+0.7	6	4,608	se.	32	nw.	29	12	8	11	5.1	0.0	0.0
Taylor	583	55	63	29.36	29.98	+.07	74.1	−0.2	90	27	86	51	5	62	35				1.69	−2.3	7	5,816	s.	24	e.	13	14	13	4	3.9	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1928*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Ohio Valley and Tennessee							**62.8**	**−2.1**										**60**	**3.03**	**−0.7**										**5.0**		
Chattanooga	762	189	213	29.15	29.96	−0.03	66.4	−2.4	87	11	77	45	9	56	37	56	49	61	4.39	+0.6	13	5,568	sw.	30	nw.	27	10	10	11	5.2	0.0	0.0
Knoxville	995	102	111	28.92	29.96	−.03	65.2	−2.2	89	3	76	44	9	54	38	56	50	66	6.17	+2.4	11	4,063	sw.	28	w.	18	11	6	14	5.5	0.0	0.0
Memphis	399	76	97	29.53	29.95	−.01	69.4	−1.2	86	17	78	48	8	60	28	60	54	63	2.51	−1.7	6	4,872	sw.	35	w.	21	15	5	11	4.2	0.0	0.0
Nashville	546	168	191	29.40	29.98	.00	66.4	−1.8	87	11	76	47	8	56	35	56	49	59	2.89	−1.0	10	6,228	ne.	36	nw.	19	13	8	10	4.7	0.0	0.0
Lexington	989	193	230	28.93	29.98	−.01	62.2	−2.1	85	3	72	38	8	53	32	----	----	----	2.12	−1.4	7	8,301	sw.	26	nw.	1	15	10	6	4.0	0.0	0.0
Louisville	525	188	234	29.40	29.98	.00	63.7	−2.9	87	10	73	41	8	54	33	55	49	64	5.63	+1.9	9	6,647	n.	29	nw.	5	10	13	8	4.7	0.0	0.0
Evansville	431	76	116	29.52	29.98	+.01	65.5	−1.2	86	10	76	43	8	56	32	56	48	59	5.11	+1.2	13	5,792	s.	39	sw.	18	11	9	11	5.1	0.0	0.0
Indianapolis	822	194	230	29.09	29.97	.00	61.4	−1.5	86	10	71	37	7	52	30	52	43	55	3.04	−0.8	13	7,237	ne.	29	n.	10	10	13	8	5.2	0.0	0.0
Royal Center	736	11	55	29.18	29.98	------	58.6	------	83	10	71	34	12	46	40	----	----	----	2.53	------	15	6,501	n.	31	w.	4	11	12	8	4.9	0.0	0.0
Terre Haute	575	96	129	29.35	29.96	------	62.9	------	88	10	74	40	12	52	31	54	46	58	2.55	------	8	6,113	n.	30	sw.	4	10	12	9	5.2	0.0	0.0
Cincinnati	627	11	51	29.30	29.98	−.01	61.8	−1.3	87	10	73	38	8	51	35	53	45	58	0.76	−2.9	10	4,642	sw.	20	ne.	7	10	12	9	5.2	0.0	0.0
Columbus	822	179	222	29.10	29.97	−.01	60.6	−1.7	87	10	71	36	7	50	32	52	43	56	1.51	−2.1	12	5,840	nw.	35	nw.	30	13	13	5	4.2	0.0	0.0
Dayton	899	137	173	29.02	29.96	------	61.0	−1.6	87	10	72	36	8	50	35	52	44	59	1.48	−2.1	12	5,491	sw.	28	nw.	30	9	15	7	5.3	0.0	0.0
Elkins	1,947	59	67	27.94	29.98	−.02	55.7	−3.5	85	4	68	30	13	43	48	49	43	68	3.94	0.0	10	3,240	nw.	25	nw.	11	7	11	13	6.0	0.0	0.0
Parkersburg	637	77	82	29.33	29.98	−.01	61.2	−2.6	89	4	73	39	6	50	42	52	44	59	1.84	−1.6	8	3,335	nw.	18	nw.	5	11	6	14	5.7	0.0	0.0
Pittsburgh	842	353	410	29.06	29.96	−.03	59.0	−3.4	86	4	69	37	13	49	38	51	44	61	1.09	−2.1	11	6,009	nw.	29	nw.	5	9	11	11	5.4	0.0	0.0
Lower Lake Region							**56.1**	**−1.3**										**64**	**1.86**	**−1.4**										**5.1**		
Buffalo	767	247	280	29.11	29.94	−.03	52.0	−2.6	73	4	59	33	7	45	34	49	47	86	1.13	−2.0	6	7,880	sw.	42	w.	5	14	4	13	5.4	0.0	0.0
Canton	448	10	61	29.43	29.90	------	53.2	−3.0	85	5	64	28	13	43	39	----	----	----	1.51	−1.3	17	5,189	w.	36	sw.	5	10	12	9	5.5	0.0	0.0
Ithaca	836	5	100	29.05	29.95	------	54.6	------	88	5	66	29	8	43	43	48	42	64	2.90	−0.5	8	5,133	nw.	23	nw.	13	6	14	11	6.1	0.0	0.0
Oswego	335	76	91	------	29.93	−.04	52.0	−3.2	81	5	60	34	8	44	39	----	----	73	2.39	−0.6	11	------	w.	29	nw.	11	7	12	12	----	0.0	0.0
Rochester	523	86	102	29.38	29.95	−.02	56.2	−0.9	86	4	66	34	7	47	40	48	40	59	2.56	−0.4	5	4,452	w.	36	w.	5	10	12	9	5.3	0.0	0.0
Syracuse	597	97	113	29.30	29.94	−.04	55.6	−1.7	86	4	65	33	7	46	38	----	----	----	1.39	−2.0	8	6,014	nw.	33	w.	5	7	14	10	5.8	0.0	0.0
Erie	714	130	166	29.19	29.96	−.02	56.0	−0.8	82	10	64	36	13	48	33	49	42	61	0.65	−2.8	5	6,719	sw.	31	sw.	5	14	11	6	3.9	0.0	0.0
Cleveland	762	190	201	29.15	29.97	−.01	57.0	−0.9	85	4	65	38	7	49	36	50	42	59	2.04	−1.1	8	6,205	ne.	31	n.	12	10	13	8	4.8	0.0	0.0
Sandusky	629	5	67	29.29	29.97	−.01	58.5	−0.7	90	10	68	40	13	49	36	----	----	----	1.92	−1.2	10	4,944	sw.	29	w.	19	11	13	7	4.9	0.0	0.0
Toledo	628	208	243	29.29	29.97	.00	59.1	−0.3	89	10	68	35	7	50	31	51	44	59	1.44	−2.0	11	7,549	sw.	30	n.	11	15	11	5	3.9	0.0	0.0
Fort Wayne	856	113	124	29.04	29.96	------	59.8	−0.4	89	10	71	35	7	49	32	51	44	60	4.42	------	10	5,699	sw.	26	sw.	4	7	19	5	5.0	0.0	0.0
Detroit	730	218	258	29.18	29.97	.00	58.2	+0.2	83	4	68	34	7	49	27	49	42	59	2.57	−0.6	12	5,344	sw.	26	sw.	4	10	11	10	5.0	0.0	0.0
Upper Lake Region							**53.3**	**+0.5**										**66**	**2.01**	**−1.2**										**4.9**		
Alpena	609	13	92	29.29	29.96	−.01	50.4	−0.1	86	3	60	32	7	41	44	45	39	69	1.31	−1.7	10	6,962	nw.	37	nw.	11	13	9	9	5.0	0.0	0.0
Escanaba	612	54	60	29.31	29.97	.00	50.2	+0.6	75	3	58	32	12	42	30	39	45	70	1.44	−1.5	12	6,436	s.	31	n.	4	14	8	9	4.6	T.	0.0
Grand Haven	632	54	89	29.28	29.96	.00	53.1	−1.4	77	3	62	35	13	44	32	47	41	65	2.08	−1.1	11	6,523	w.	28	s.	3	17	7	7	4.4	0.0	0.0
Grand Rapids	707	70	87	29.20	29.97	.00	58.0	0.0	86	3	68	35	12	48	37	50	41	58	3.09	−0.4	9	3,509	nw.	22	w.	4	11	11	9	5.1	0.0	0.0
Houghton	668	64	99	29.24	29.97	.00	51.1	+1.6	86	9	61	31	6	41	45	----	----	----	1.72	−1.6	5	6,348	w.	28	n.	20	8	9	14	6.4	0.0	0.0
Lansing	878	6	49	29.02	29.96	------	56.1	−0.8	87	3	67	31	7	45	40	50	45	70	4.47	+1.0	11	3,428	nw.	22	n.	11	13	10	8	4.4	0.0	0.0
Ludington	637	60	66	29.27	29.97	------	50.7	------	71	9	59	32	7	42	29	46	42	74	1.62	------	8	5,501	n.	29	s.	3	17	8	6	3.6	0.0	0.0
Marquette	734	77	111	29.18	29.98	+.01	50.4	+1.4	80	9	58	33	6	42	37	44	38	65	1.94	−1.0	7	6,232	nw.	42	sw.	8	8	12	11	5.9	0.0	0.0
Port Huron	638	70	120	29.26	29.96	−.01	54.0	−1.2	84	4	64	33	13	44	31	48	42	69	2.29	−0.7	10	5,848	ne.	30	nw.	5	11	15	5	4.6	0.0	0.0
Sault Sainte Marie	614	11	52	29.27	29.98	+.03	47.4	−1.6	72	20	56	30	7	38	35	42	37	73	1.64	−1.6	10	5,993	nw.	28	nw.	11	11	9	11	5.4	0.0	0.0
Chicago	673	7	131	29.25	29.97	+.01	58.2	+0.7	90	3	66	41	13	50	36	49	42	62	1.59	−2.0	8	6,704	ne.	26	n.	4	13	12	6	4.5	0.0	0.0
Green Bay	617	109	141	29.29	29.95	.00	56.4	+1.5	84	3	67	36	7	46	39	48	41	63	1.17	−2.4	13	6,463	s.	29	nw.	30	8	13	10	5.6	0.0	0.0
Milwaukee	681	125	221	29.24	29.97	+.01	54.9	+0.8	87	3	63	39	12	47	34	48	41	64	2.44	−0.9	9	7,307	se.	31	n.	24	13	10	8	4.5	0.0	0.0
Duluth	1,133	5	47	28.76	29.98	+.02	52.8	+5.5	84	9	64	33	12	41	38	45	37	60	0.95	−2.3	4	7,029	ne.	36	sw.	7	11	12	8	4.9	0.0	0.0
North Dakota							**59.0**	**+5.0**										**48**	**1.04**	**−1.3**										**4.4**		
Moorhead	940	50	58	28.95	29.96	+.02	59.1	+4.0	92	23	73	30	5	45	46	48	36	46	0.46	−2.4	7	5,721	n.	24	sw.	7	12	8	11	5.2	0.0	0.0
Bismarck	1,674	8	57	28.19	29.96	+.04	60.4	+5.9	96	23	74	34	3	47	41	49	38	48	0.58	−1.7	6	6,099	e.	26	s.	13	18	6	7	3.7	0.0	0.0
Devils Lake	1,478	11	44	28.41	29.97	+.03	57.0	+4.8	94	23	71	26	11	43	43	46	35	52	2.44	+0.2	6	6,044	n.	29	nw.	10	16	7	8	4.3	0.0	0.0
Ellendale	1,457	10	56	28.43	29.99	------	58.1	------	92	7	73	30	5	43	46	----	----	----	0.67	------	8	9,292	nw.	36	n.	9	11	10	10	5.5	0.0	0.0
Grand Forks	833	12	67	------	------	------	57.4	------	95	23	72	27	5	43	49	48	----	----	0.80	------	7	------	nw.	----	s.	----	12	13	6	4.3	0.0	0.0
Williston	1,878	41	48	27.99	29.95	+.02	59.6	+5.6	92	23	73	29	4	46	43	47	35	45	0.67	−1.4	6	5,396	se.	29	n.	9	18	9	4	3.3	0.0	0.0
Upper Mississippi Valley							**63.2**	**+1.7**										**56**	**2.56**	**−1.6**										**4.7**		
Minneapolis	918	102	208	28.96	29.93	------	61.0	+3.3	89	9	71	41	12	51	28	----	----	----	2.38	−1.3	8	7,468	n.	38	nw.	9	9	13	9	5.6	0.0	0.0
St. Paul	837	236	261	29.07	29.97	+.03	60.4	+2.5	86	9	70	41	27	50	30	----	----	----	2.16	−1.1	7	7,496	nw.	37	nw.	9	8	14	9	5.3	0.0	0.0
La Crosse	714	11	48	29.18	29.95	+.01	61.6	+2.3	93	24	73	38	12	50	37	52	44	58	2.99	−0.8	6	2,801	nw.	18	sw.	2	12	9	10	4.9	0.0	0.0
Madison	974	70	78	28.92	29.96	.00	60.0	+2.4	87	24	70	37	12	50	36	51	43	58	2.97	−0.9	10	5,071	nw.	26	s.	2	9	14	8	5.2	0.0	0.0
Wausau	1,247	4	----	28.64	29.97	------	57.0	------	89	24	69	30	12	45	37	----	----	----	2.29	------	7	------	nw.	----	----	----	14	6	11	5.0	0.0	0.0
Charles City	1,015	10	49	28.90	29.97	+.03	60.5	+2.7	90	24	72	34	12	48	37	51	42	53	2.44	−2.5	8	4,291	nw.	27	sw.	2	20	8	3	3.0	0.0	0.0
Davenport	606	71	79	29.30	29.96	+.01	64.2	+2.9	88	9	76	38	7	53	34	53	44	53	1.08	−2.9	6	4,642	nw.	21	e.	26	11	14	9	4.5	0.0	0.0
Des Moines	861	84	97	29.05	29.95	+.02	64.2	+2.9	91	24	76	40	28	53	36	53	44	53	2.63	−1.9	9	4,699	n.	29	sw.	2	12	8	11	5.1	0.0	0.0
Dubuque	700	81	96	29.21	29.95	.00	62.4	+2.1	90	24	74	39	12	51	36	52	44	56	1.55	−2.7	11	4,323	nw.	26	nw.	24	9	14	8	5.0	0.0	0.0
Keokuk	614	64	78	29.30	29.96	+.02	64.8	+1.0	88	10	76	40	7	54	32	54	45	53	2.55	−1.4	8	4,737	n.	24	w.	24	9	9	13	5.4	0.0	0.0
Cairo	358	87	93	29.59	29.96	.00	66.9	−1.5	88	10	76	47	8	58	32	58	52	64	1.75	−2.0	12	5,892	n.	27	sw.	4	10	7	14	5.5	0.0	0.0
Peoria	609	11	45	29.32	29.98	+.02	63.3	+1.6	89	3	76	35	12	51	37	54	46	59	3.21	−0.8	10	4,262	s.	16	sw.	3	15	14	2	3.6	0.0	0.0
Springfield, Ill.	636	10	91	29.28	29.95	.00	64.0	+0.8	92	10	76	38	7	52	34	55	47	57	4.61	+0.2	8	5,675	n.	22	ne.	10	13	11	7	4.4	0.0	0.0
Hannibal	534	74	109	29.39	29.96	+.02	64.9	+1.3	91	10	76	40	28	54	38	----	----	----	3.28	−1.7	8	5,812	sw.	22	n.	25	13	10	8	4.6	0.0	0.0
St. Louis	568	265	303	29.36	29.96	+.01	66.6	−0.3	91	10	76	42	7	57	30	56	48	56	2.18	−2.2	11	8,016	sw.	38	sw.	14	16	8	7	4.0	0.0	0.0
Missouri Valley							**64.5**	**+3.0**										**54**	**2.73**	**−1.4**										**4.2**		
Columbia, Mo.	784	6	84	29.13	29.96	+.02	65.7	+1.4	91	10	78	40	28	54	36	----	----	----	1.74	−3.1	11	4,981	s.	23	n.	30	12	11	8	4.6	0.0	0.0
Kansas City	963	161	181	28.92	29.94	+.02	67.8	+3.0	91	30	78	49	13	57	30	56	47	54	2.34	−2.3	9	6,712	s.	51	n.	30	14	12	5	3.8	0.0	0.0
St. Joseph	967	11	49	28.91	29.94	------	67.2	------	91	9	79	44	1	55	41	55	46	55	2.09	------	7	5,565	se.	26	ne.	30	16	12	3	3.4	0.0	0.0
Springfield, Mo.	1,324	98	104	28.58	29.96	+.03	66.1	+1.6	87	10	76	45	5	56	28	56	43	58	3.97	−1.6	12	6,777	s.	33	w.	17	23	6	2	2.3	0.0	0.0
Iola	984	11	50	28.91	29.94	+.02	67.2	+2.0	94	30	80	42	5	54	37	----	----	----	4.34	−0.9	10	4,114	n.	19	s.	3	16	8	7	4.1	0.0	0.0
Topeka	987	92	107	------	------	------	66.9	+2.6	96	30	79	45	5	55	36	----	----	----	2.46	−2.4	8	6,346	sw.	29	nw.	20	16	11	4	3.7	0.0	0.0
Lincoln	1,189	11	81	28.69	29.94	+.03	64.6	+2.9	93	24	77	39	1	52	47	54	45	55	2.75	−1.5	7	6,307	n.	30	ne.	30	14	5	12	4.7	0.0	0.0
Omaha	1,105	115	122	28.78	29.95	+.03	65.1	+2.7	92	24	75	46	12	55	36	54	44	52	1.97	−1.8	8	5,120	n.	23	n.	4	12	11	8	4.8	0.0	0.0
Valentine	2,598	47	54	27.29	29.98	+.08	61.0	+4.8	92	1	74	34	21	48	45	49	30	53	1.62	−1.7	10	5,925	n.	32	sw.	7	13	11	7	4.5	0.0	0.0
Sioux City	1,135	94	164	28.77	29.97	+.05	63.0	+2.6	92	9	74	39	12	51	45	53	44	56	5.36	+1.0	12	7,140	n.	35	s.	8	11	11	9	5.0	0.0	0.0
Huron	1,306	59	74	28.58	29.98	+.06	60.8	+4.4	95	9	75	34	12	47	53	50	38	50	1.25	−1.7	7	6,413	s.	33	s.	7	16	9	6	4.5	0.0	0.0
Pierre	1,572	70	75	------	29.98	+.07	63.0	+5.0	95	7	76	39	4	50	46	----	----	50	1.30	−0.8	6	6,080	se.	31	ne.	30	12	8	11	----	0.0	0.0
Yankton	1,233	49	57	28.66	29.97	+.05	62.4	+3.0	95	9	75	37	12	49	52	----	----	----	3.63	−0.2	11	4,750	n.	30	s.	7	13	13	5	4.6	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1928*—Continued

District and station	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew-point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with .01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*		°*F.*	°*F.*		°*F.*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles*								*0–10*	*In.*	*In.*
Northern Slope							**57.6**	**+4.8**										**54**	**1.39**	**−0.9**										**5.0**		
Billings	3,140	5					60.8		93	26	78	22	4	43	54				0.75		6		nw.				10	13	8		0.0	0.0
Havre	2,505	11	44	27.34	29.95	+.05	60.6	+7.2	96	22	76	33	4	45	51	47	36	46	0.45	−1.6	5	4,515	sw.	28	sw.	1	10	17	4	4.5	0.0	0.0
Helena	4,110	87	112	25.82	29.97	+.04	58.0	+6.4	86	26	72	32	3	45	37	46	36	49	0.24	−1.7	3	5,640	sw.	40	sw.	29	11	11	9	5.5	0.0	0.0
Kalispell	2,973	48	56	26.94	29.97	+.09	56.6	+5.2	84	25	70	30	3	43	38	46	36	55	0.61	−1.4	6	4,360	nw.	21	w.	29	18	10	3	3.6	T.	0.0
Miles City	2,371	48	55	27.46	29.99	+.08	62.2	+5.5	91	22	75	33	3	49	42	49	37	45	0.47	−1.5	3	4,262	s.	24	nw.	30	14	13	4	3.8	0.0	0.0
Rapid City	3,259	59	58	26.62	30.00	+.10	59.8	+5.8	87	7	71	38	12	48	36	49	40	51	1.94	−1.0	12	5,239	n.	29	s.	12	9	10	12	5.6	0.0	0.0
Cheyenne	6,088	84	101	24.05	29.97	+.12	52.7	+2.4	79	1	64	28	4	42	34	43	37	66	2.67	+0.2	15	7,020	n.	48	w.	28	8	10	13	6.1	T.	0.0
Lander	5,372	60	68	24.68	29.98	+.10	55.6	+4.4	82	29	68	26	4	43	41	46	38	60	2.04	−0.9	10	3,852	sw.	36	w.	1	11	14	6	5.2	T.	0.0
Sheridan	3,790	10	47	26.11	29.98		57.4		87	6	72	25	4	43	52	47	38	55	1.62		8	3,463	nw.	26	nw.	30	9	16	6	5.0	0.0	0.0
Yellowstone Park	6,241	11	48	23.93	30.00	+.09	50.3	+2.9	78	25	64	21	3	37	39	40	32	57	0.51	−1.4	10	5,160	sw.	28	sw.	27	5	16	10	6.2	0.1	0.0
North Platte	2,821	11	51	27.06	29.95	+.07	62.5	+3.8	96	1	76	35	4	49	48	52	44	61	3.62	+0.8	13	4,825	n.	25	ne.	2	14	8	9	4.9	0.0	0.0
Middle Slope							**63.6**	**+1.1**										**61**	**2.74**	**−0.9**										**4.8**		
Denver	5,292	106	113	24.76	29.97	+.13	57.7	+1.5	89	30	68	36	3	47	34	48	40	60	3.06	+0.8	16	4,849	s.	28	n.	24	11	9	11	5.3	0.0	0.0
Pueblo	4,685	80	86	25.31	29.96	+.13	59.8	+0.6	91	30	72	38	3	48	47	49	41	60	3.56	+1.9	16	4,177	nw.	32	nw.	7	5	18	8	5.9	0.0	0.0
Concordia	1,392	50	58	28.51	29.97	+.06	65.0	+1.8	94	30	77	43	22	53	38	55	47	58	1.24	−2.9	9	5,323	s.	23	s.	2	11	12	8	5.0	0.0	0.0
Dodge City	2,509	11	51	27.39	29.96	+.09	62.9	−0.6	92	9	75	41	5	51	39	54	48	66	3.85	+1.0	11	5,732	se.	28	sw.	1	18	6	7	3.7	0.0	0.0
Wichita	1,358	139	158	28.51	29.93	+.03	66.5	+1.4	91	30	77	46	4	56	33	57	50	60	2.79	−2.2	12	7,943	se.	35	s.	2	13	11	7	4.3	0.0	0.0
Broken Arrow	765	11	56	29.14	29.95		68.6		93	31	78	47	5	59	26				2.22		7	8,665	s.	48	s.	17	12	7	12	5.2	0.8	0.0
Oklahoma City	1,214	10	47	28.66	29.92	+.03	69.6	+1.9	98	31	80	46	5	59	30	59	53	62	1.92	−3.8	8	5,907	s.	27	s.	16	14	7	10	4.8	0.0	0.0
Southern Slope							**70.3**	**−0.3**										**58**	**6.05**	**+3.3**										**4.5**		
Abilene	1,738	10	52	28.13	29.90	+.03	72.4	+0.4	100	9	85	44	5	60	34	60	52	57	12.03	+8.1	12	6,305	s.	30	sw.	11	13	11	7	4.6	0.0	0.0
Amarillo	3,676	10	49	26.26	29.94	+.10	65.5	+1.4	94	31	78	40	4	53	39	54	47	61	6.48	+2.8	15	5,457	s.	26	se.	2	20	4	7	3.9	0.0	0.0
Del Rio	944	64	71	28.90	29.86	+.01	75.8	−1.2	100	28	86	55	6	66	32	64	57	59	3.76	+1.4	9	5,870	se.	29	se.	2	12	9	10	4.9	0.9	0.0
Roswell	3,566	75	85	26.33	29.88	+.06	67.6	−1.8	97	31	81	45	5	54	38	54	44	53	1.92	+0.8	6	4,874	s.	32	nw.	14	14	13	4	4.5	0.0	0.0
Southern Plateau							**67.7**	**+2.3**										**43**	**0.95**	**+0.5**										**3.0**		
El Paso	3,778	152	175	26.14	29.84	+.06	71.8	+0.3	97	29	84	51	13	60	31	54	39	38	0.96	+0.6	8	7,907	w.	38	w.	8	15	14	2	3.7	0.0	0.0
Santa Fe	7,013	38	53	23.27	29.87	+.06	56.1	+0.4	82	31	68	33	11	45	30	45	35	54	2.80	+1.5	14	3,651	sw.	21	sw.	1	11	13	7	5.0	2.0	0.0
Flagstaff	6,907	10	59	23.36	29.86	+.08	52.3	+1.6	81	29	68	24	4	36	43	41		56	0.62		5		nw.		s.		7	20	4		T.	0.0
Phoenix	1,108	10	82	28.65	29.78	.00	79.4	+4.4	103	26	94	58	16	65	37	58	41	30	0.03	0.0	1	3,873	w.	26	s.	8	21	8	2	2.4	0.0	0.0
Yuma	141	9	54	29.64	29.79	.00	79.2	+3.0	106	26	95	54	16	63	41	60	46	39	T.	0.0	0	3,417	s.	26	se.	1	29	2	0	1.0	0.0	0.0
Independence	3,957	5	25				67.2	+4.2	94	28		42	9		38				0.77		4		nw.				16	12	3		0.0	
Middle Plateau							**61.6**	**+5.7**										**45**	**0.91**	**−0.1**										**4.0**		
Reno	4,532	74	81	25.43	29.87	−.04	62.3	+8.7	88	25	78	31	3	47	40	48	36	46	0.13	−0.5	4	4,510	w.	20	w.	14	18	11	2	3.6	0.0	0.0
Tonopah	6,090	12	20				60.2		84	29	70	35	2	50	28	45	29	35	0.16		2		se.									
Winnemucca	4,344	18	56	25.59	29.93	+.02	60.5	+6.6	89	26	78	25	3	43	48	46	34	47	0.06	−0.8	3	3,595	ne.	24	se.	9	17	14	0	3.3	0.0	0.0
Modena	5,473	10	43	24.59	29.86	+.04	57.4	+3.9	86	28	73	27	4	42	46	45	33	51	1.76	+0.9	10	6,405	w.	35	sw.	1	15	15	1	3.7	0.0	0.0
Salt Lake City	4,360	163	203	25.59	29.90	+.04	63.8	+6.4	89	29	74	39	4	54	35	49	37	41	1.33	−0.6	8	5,373	nw.	32	se.	9	10	14	7	5.1	0.0	0.0
Grand Junction	4,602	60	68	25.36	29.90	+.07	63.9	+2.8	91	29	77	37	4	51	35	49	38	49	1.29	+0.4	11	4,206	se.	29	s.	11	12	12	7	4.5	0.0	0.0
Northern Plateau							**62.3**	**+6.1**										**46**	**0.41**	**−1.3**										**3.5**		
Baker	3,471	48	53	26.45	30.01	+.05	56.8	+5.1	90	25	72	25	2	41	42	45	33	48	0.18	−1.6	4	4,375	se.	18	n.	12	17	9	5	3.9	T.	0.0
Boise	2,739	78	86	27.13	29.95	+.01	64.6	+7.5	94	25	79	31	3	51	39	50	36	42	0.01	−1.4	1	4,117	se.	22	se.	6	17	11	3	3.5	0.0	0.0
Lewiston	757	40	48	29.20	30.00	+.04	64.8	+5.3	101	25	81	34	3	48	45				0.23	−1.4	4	2,298	e.	22	nw.	21	19	11	1	2.9	0.0	0.0
Pocatello	4,477	60	68	25.46	29.92	+.03	60.6	+6.8	86	25	74	31	3	47	36	47	36	46	1.53	−0.7	7	5,034	se.	28	sw.	29	9	16	6	4.9	0.0	0.0
Spokane	1,929	101	110	27.96	29.99	+.03	61.6	+6.1	97	25	75	33	3	48	40	49	38	49	0.48	−0.9	7	3,756	s.	23	sw.	27	15	14	2	3.6	0.0	0.0
Walla Walla	991	57	65	28.91	29.98	+.02	65.6	+6.0	95	25	79	39	3	52	38	52	40	44	0.02	−1.6	2	2,936	s.	27	w.	21	21	9	1	2.5	0.0	0.0
North Pacific Coast Region							**57.1**	**+3.5**										**71**	**0.92**	**−1.4**										**5.5**		
North Head	211	11	56	29.82	30.05	+.02	52.4	+1.5	71	13	56	44	1	49	24	50	47	85	0.58	−1.8	7	11,693	n.	60	s.	28	1	9	21	8.3	0.0	0.0
Port Angeles	29	8	53		30.09		53.7		75	19	63	35	2	44	29				0.29	−1.0	3	4,229	sw.	26	w.	11	12	10	9		0.0	0.0
Seattle	125	215	250	29.92	30.05	+.04	58.2	+3.7	82	20	67	41	2	50	28	51	45	66	0.31	−1.5	4	5,130	n.	31	s.	28	10	8	13	5.5	0.0	0.0
Tacoma	194	172	201	29.86	30.06	+.04	58.2	+4.1	80	20	68	40	2	49	30				0.70	−1.5	4	5,321	n.	30	sw.	28	14	7	10	4.9	0.0	0.0
Tatoosh Island	86	9	53	29.98	30.08	+.07	51.6	+2.0	62	10	55	43	2	48	14	49	47	87	3.37	−0.7	12	7,667	s.	38	sw.	28	4	13	14	7.0	0.0	0.0
Yakima	1,071	5																	0.01		1		nw.	18	n.	1	15	8	8	4.2	0.0	0.0
Medford	1,425	4	80	28.48	29.97		62.2		98	24	80	31	3	44	47	51	44	61														
Portland	153	68	106	29.88	30.04	+.01	62.4	+5.5	93	24	74	40	2	51	37	53	45	60	0.74	−2.0	4	4,028	nw.	19	w.	1	12	7	12	5.1	0.0	0.0
Roseburg	510	75	99	29.49	30.04	+.01	60.0	+4.0	96	24	74	35	2	46	43	51	44	65	0.42	−1.5	3	2,868	n.	20	sw.	28	13	16	2	3.8	0.0	0.0
Middle Pacific Coast Region							**62.8**	**+3.0**										**68**	**0.11**	**−0.9**										**3.5**		
Eureka	62	73	89	30.01	30.08	+.03	52.8	+0.8	65	28	58	40	1	48	16	50	48	86	0.12	−1.7	3	4,849	n.	27	n.	30	8	10	13	6.4	0.0	0.0
Red Bluff	332	50	56	29.54	29.89	−.06	72.6	+6.3	100	24	87	45	1	58	39	58	47	47	0.00	−1.1	0	3,927	se.	21	n.	12	27	4	0	1.7	0.0	0.0
Sacramento	69	106	117	29.82	29.89	−.05	67.2	+3.9	96	24	81	49	2	53	39	56	49	61	0.02	−0.8	1	5,642	s.	23	sw.	7	23	6	2	2.0	0.0	0.0
San Francisco	155	208	243	29.80	29.97	−.02	58.9	+2.1	77	5	65	50	24	52	26	53	49	77	0.26	−0.5	1	5,533	w.	28	w.	26	15	7	9	4.4	0.0	0.0
San Jose	141	12	110	29.81	29.96		62.6	+1.9	88	13	75	39	3	50	43				0.15	−0.4	1	4,567	nw.	21	sw.	7	19	8	4	3.1	0.0	0.0
South Pacific Coast Region							**66.4**	**+3.0**										**67**	**0.22**	**−0.2**										**5.2**		
Fresno	327	89	98	29.53	29.88	−.04	72.0	+4.9	102	24	87	46	2	58	38	57	45	46	T.	−0.4	0	5,664	nw.	25	nw.	27	23	6	2	2.2	0.0	0.0
Los Angeles	338	159	191	29.58	29.94	−.01	64.2	+2.0	93	4	71	54	9	57	36	57	53	74	0.29	−0.2	3	3,458	sw.	13	w.	5	5	15	11	6.1	0.0	0.0
San Diego	87	62	70	29.84	29.93	−.02	63.0	+2.2	80	5	67	56	9	59	19	58	55	80	0.36	0.0	5	4,266	sw.	19	sw.	8	3	11	17	7.3	0.0	0.0
West Indies																																
San Juan	82	9	54	29.88	29.96		79.4	+0.8	90	4	86	70	20	73	18				9.19	+4.4	12	7,023	e.	36	ne.	6	4	15	12	6.6	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	[1] 29.74	[1] 29.83	.00	80.8	+0.1	92	24	87	71	7	74	19				4.20	−3.6	13		nw.		nw.		2	16	13	7.1	0.0	0.0
Colon	38	7	97	[1] 29.83	[1] 29.85	+0.1	82.6	+1.9	91	30	88	74	29	78	16				12.72	+0.3	18		n.		nw.		1	12	18	7.7	0.0	0.0
Alaska																																
Juneau	80	11	54	[2] 29.85	[2] 29.94		45.6		65	27	52	32	11	40	25	43	39	80	8.25		25	4,764	se.	21	se.	19	3	5	23	8.3	T.	0.0
Hawaiian Islands																																
Honolulu	38	86	100	[2] 30.02	[2] 30.06		75.0		82	30	80	68	13	70	13	67	63	68	0.63	−1.1	5	6,255	e.	27	e.	12	15	6	10	5.1	0.0	0.0

[1] Observations taken hourly.

[2] Pressure not corrected to mean of 24 hours.

TABLE 2.—*Data furnished by the Canadian Meteorological Service, May, 1928*

Station	Altitude above mean sea level Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*Inches*	*Inches*	*Inches*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*° F.*	*Inches*	*Inches*	*Inches*
Cape Race, N. F.	99				41.2		48.0	34.5	55	26	3.41		0.0
Sydney, C. B. I.	48	29.92	29.97	0.00	47.9	+2.7	57.0	38.9	72	28	5.98	+2.21	0.0
Halifax, N. S.	88	29.86	29.97	−.01	48.1	−0.3	56.5	39.6	70	33	2.95	−1.31	0.0
Yarmouth, N. S.	65	29.80	29.87	−.11	47.6	0.0	53.5	41.7	58	32	3.25	−0.32	0.0
Charlottetown, P. E. I.	38	29.85	29.89	−.07	50.0	+3.1	57.7	42.3	70	33	2.58	−0.33	0.0
Chatham, N. B.	28	29.84	29.87	−.08	50.3	+1.8	60.6	40.1	74	28	4.36	+1.15	0.0
Father Point, Que.	20												
Quebec, Que.	296	29.59	29.91	−.03	50.3	+0.4	58.0	42.7	72	34	5.64	+2.56	0.0
Doucet, Que.	1,236				44.9		56.0	33.8	74	16	3.03		0.0
Montreal, Que.	187	29.68	29.89	−.05	54.4	−0.3	62.5	46.4	76	33	3.67	+0.72	0.0
Ottawa, Ont.	236	29.64	29.90	−.04	54.5	−0.4	64.9	44.1	82	32	2.78	+0.19	0.0
Kingston, Ont.	285	29.60	29.91	−.05	51.5	−1.4	59.1	43.9	70	33	2.12	−0.56	0.0
Toronto, Ont.	379	29.53	29.94	−.04	54.2	+1.0	64.1	44.2	82	33	0.72	−2.32	0.0
Cochrane, Ont.	930				46.3		56.1	36.6	76	26	2.23		0.0
White River, Ont.	1,244	28.60	29.92	−.03	47.4	+1.7	59.8	35.1	75	19	2.02	+0.07	0.0
London, Ont.	808				54.1		66.7	41.5	85	28	2.10		0.0
Southampton, Ont.	656	29.24	29.96	.00	47.8	−2.9	57.0	38.5	81	26	2.12	−0.32	0.0
Parry Sound, Ont.	688	29.23	29.93	−.02	49.7	−1.4	60.1	39.4	82	28	1.41	−1.52	T.
Port Arthur, Ont.	644	29.26	29.97	+.01	50.4	+4.5	60.7	40.1	76	30	1.49	−0.66	0.0
Winnipeg, Man.	760	29.15	29.98	+.02	55.9	+4.3	69.4	42.4	96	26	3.33	+1.05	0.0
Minnedosa, Man.	1,690	28.17	29.98	+.02	54.5	+6.1	69.2	39.8	94	26	1.65	+0.20	0.0
Le Pas, Man.	860				49.6		62.9	36.3	78	21	0.67		0.0
Qu'Appelle, Sask.	2,115	27.72	29.95	+.01	56.5	+6.7	70.6	42.4	90	25	0.60	−1.05	0.8
Moose Jaw, Sask.	1,759				58.1		74.2	42.1	96	23	0.66		0.0
Swift Current, Sask.	2,392	27.40	29.89	−.03	59.6	+8.9	77.7	41.6	97	23	0.44	−1.32	0.0
Medicine Hat, Alb.	2,144												
Calgary, Alb.	3,428												
Banff, Alb.	4,521												
Prince Albert, Sask.	1,450	28.40	29.97	+.02	54.7	+7.1	68.8	40.6	95	22	0.92	−0.34	0.0
Battleford, Sask.	1,502	28.19	29.92	.00	55.8	+4.8	71.2	40.5	94	12	0.53	−1.09	0.0
Edmonton, Alb.	2,150												
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.80	30.05	+.05	55.4	+2.9	63.6	47.3	78	40	0.32	−1.16	0.0
Barkerville, B. C.	4,180												
Estevan Point, B. C.	20												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151	29.91	30.07	+.01	68.7	−0.7	74.8	62.7	80	54	6.50	+1.84	0.0

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Cochrane, Ont.	930				25.9		36.0	15.8	61	−1	2.11		7.1
Montreal, Que.	187	29.66	29.87	−.13	37.2	−2.5	44.1	30.3	69	17	3.41	+1.17	11.8
Winnipeg, Man.	760	29.12	29.98	−.04	34.0	−1.9	43.6	24.5	76	6	1.20	+0.15	2.4
Minnedosa, Man.	1,690	28.12	29.98	−.03	29.9	−6.1	40.7	19.1	73	−3	1.43	+0.37	12.0
Medicine Hat, Alb.	2,144	27.57	29.85	−.07	41.4	−3.1	53.2	29.6	85	10	0.43	−0.31	4.1
Calgary, Alb.	3,428	26.30	29.92	+.02	36.0	−3.6	47.4	24.7	78	12	0.95	+0.31	9.5
Banff, Alb.	4,521	25.24	29.87	−.03	33.4	−1.9	45.0	21.7	66	7	1.02	−0.06	8.1
Edmonton, Alb.	2,150	27.57	29.89	.00	33.5	−6.4	43.3	23.7	78	4	0.92	+0.04	8.1
Kamloops, B. C.	1,262	28.59	29.89	−.04	47.5	−1.4	57.8	37.2	76	25	0.23	−0.16	T.
Barkerville, B. C.	4,180	25.51	29.84	−.02	32.1	−1.0	41.6	22.6	57	8	3.65	+1.83	27.9
Estevan Point, B. C.	20				44.8		50.9	38.8	56	30	6.77		0.0
Prince Rupert, B. C.	170				44.2		51.5	36.9	60	27	5.21		3.2

Chart I. Departure (°F.) of the Mean Temperature from the Normal, May, 1928

Chart I. Departure (°F.) of the Mean Temperature from the Normal, May, 1928

Shaded portions show excess (+).
Unshaded portions show deficiency (—).
Lines show amount of excess or deficiency.
Statute Miles
Kilometers

Chart II. Tracks of Centers of Anticyclones, May, 1928. (Inset) Departure of Monthly Mean Pressure from Normal

(Plotted by Wilfred P. Day)

Chart III. Tracks of Centers of Cyclones, May, 1928. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day)

Chart III. Tracks of Centers of Cyclones, May, 1928. (Inset) Change in Mean Pressure from Preceding Month

(Plotted by Wilfred P. Day)

Chart IV. Percentage of Clear Sky between Sunrise and Sunset, May, 1928

Chart V. Total Precipitation, Inches, May, 1928. (Inset) Departure of Precipitation from Normal

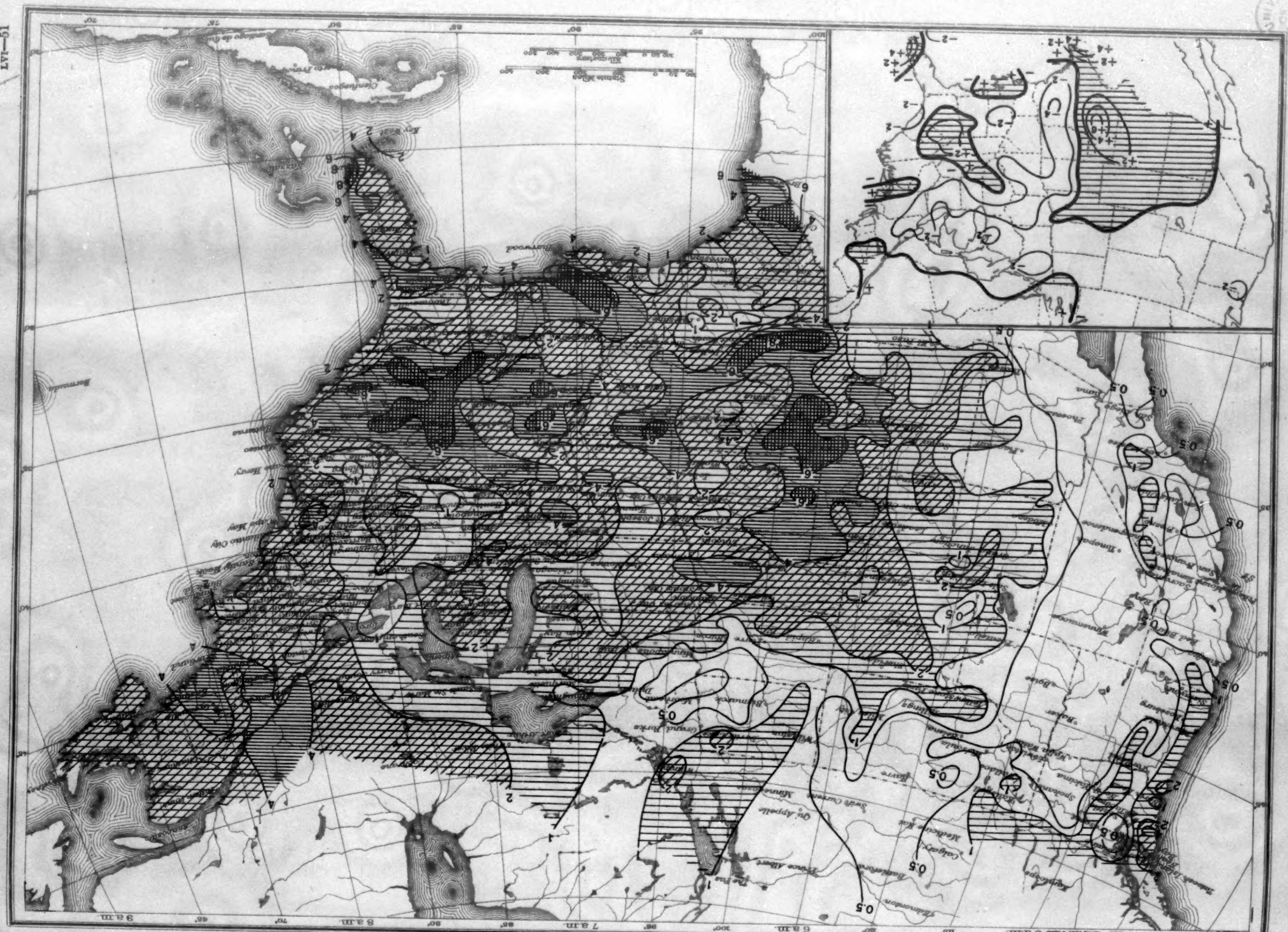
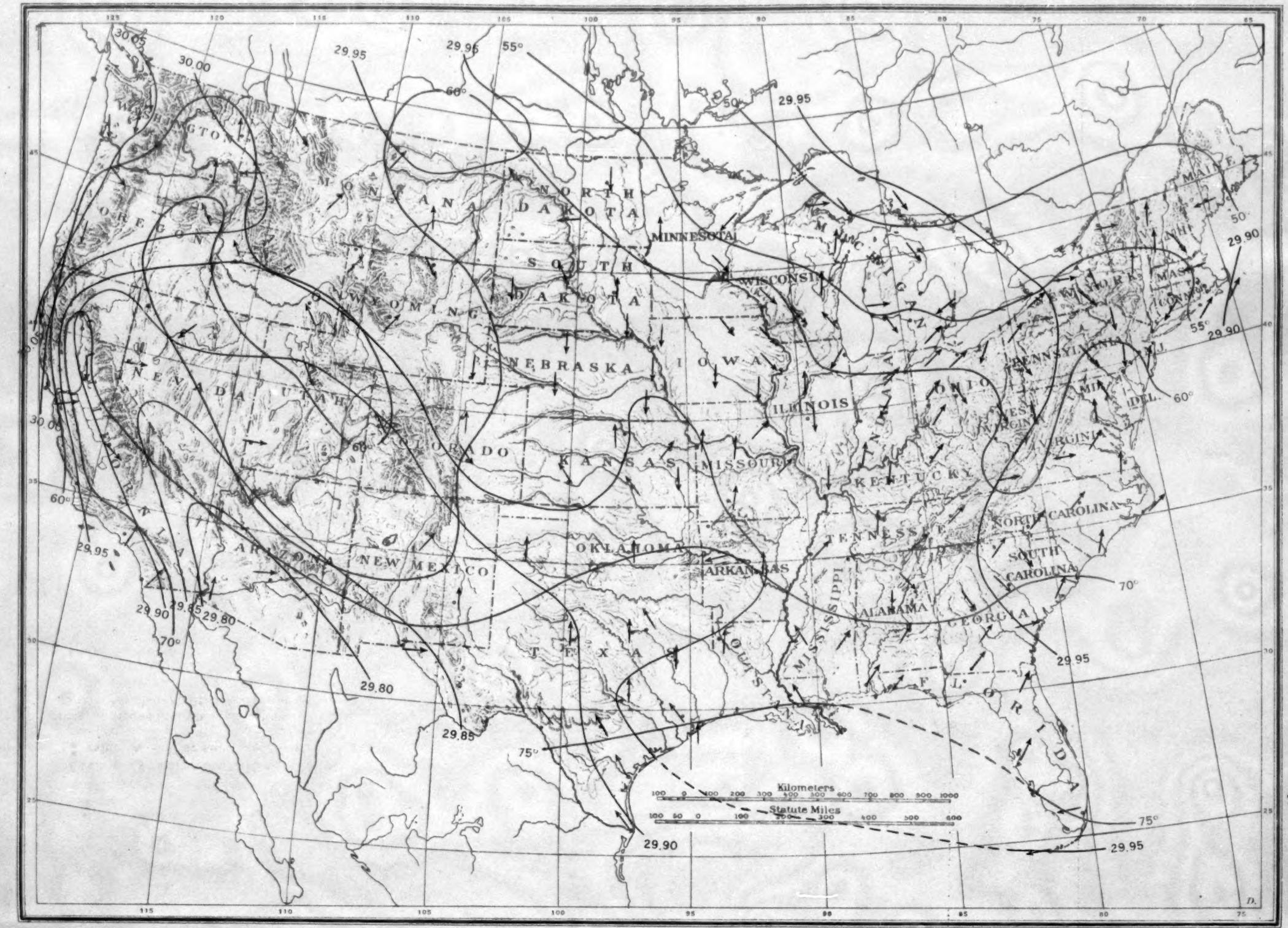


Chart V. Total Precipitation, Inches, May, 1928. (Inset) Departure of Precipitation from Normal

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, May, 1928



May, 1928. M. W. R.

Chart VIII. Weather Map of North Atlantic Ocean, May 4, 1928

(Plotted by F. A. Young)

Chart VIII. Weather Map of North Atlantic Ocean, May 4, 1928

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, • rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

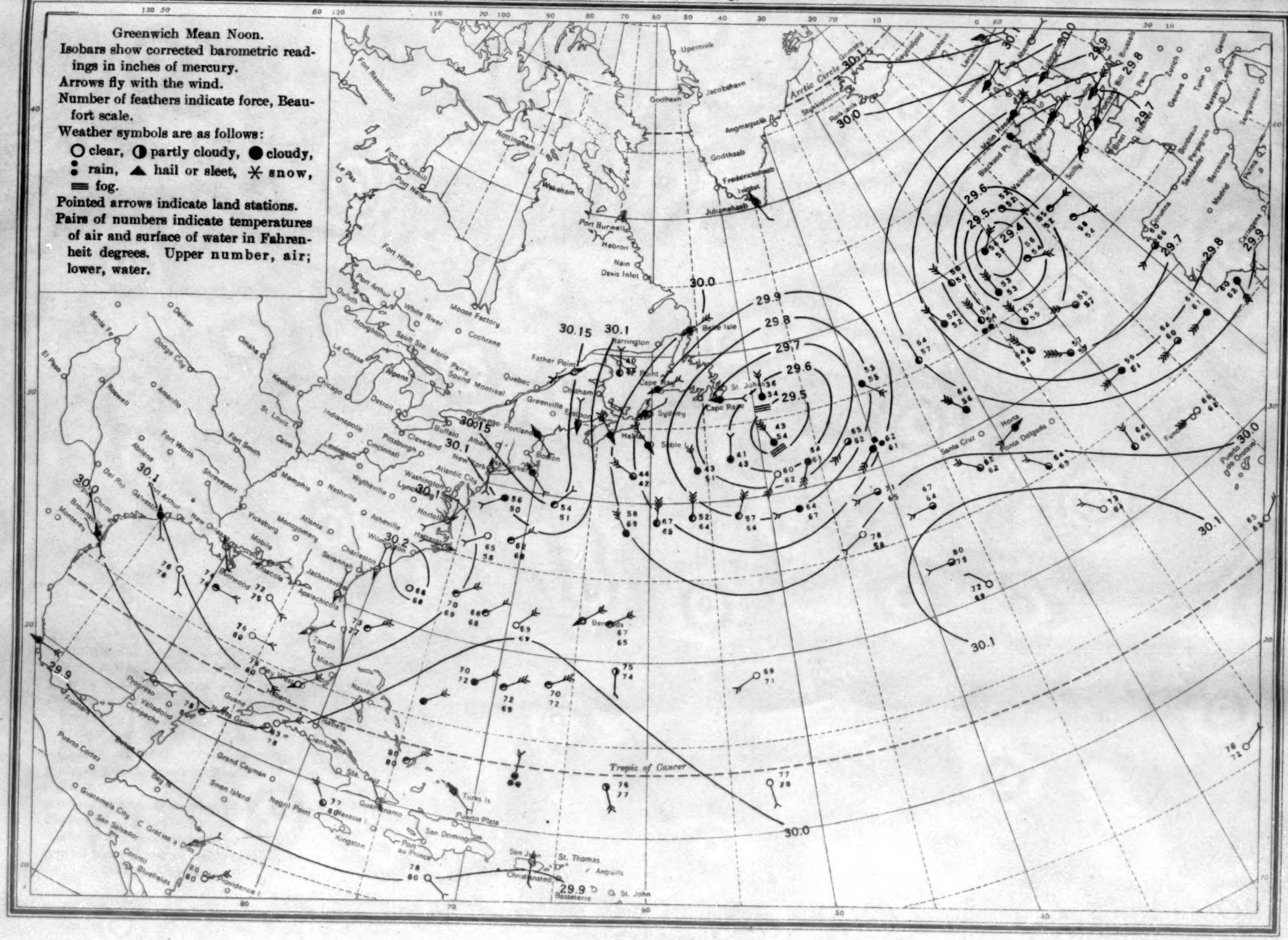


Chart IX. Weather Map of North Atlantic Ocean, May 5, 1928

(Plotted by F. A. Young)

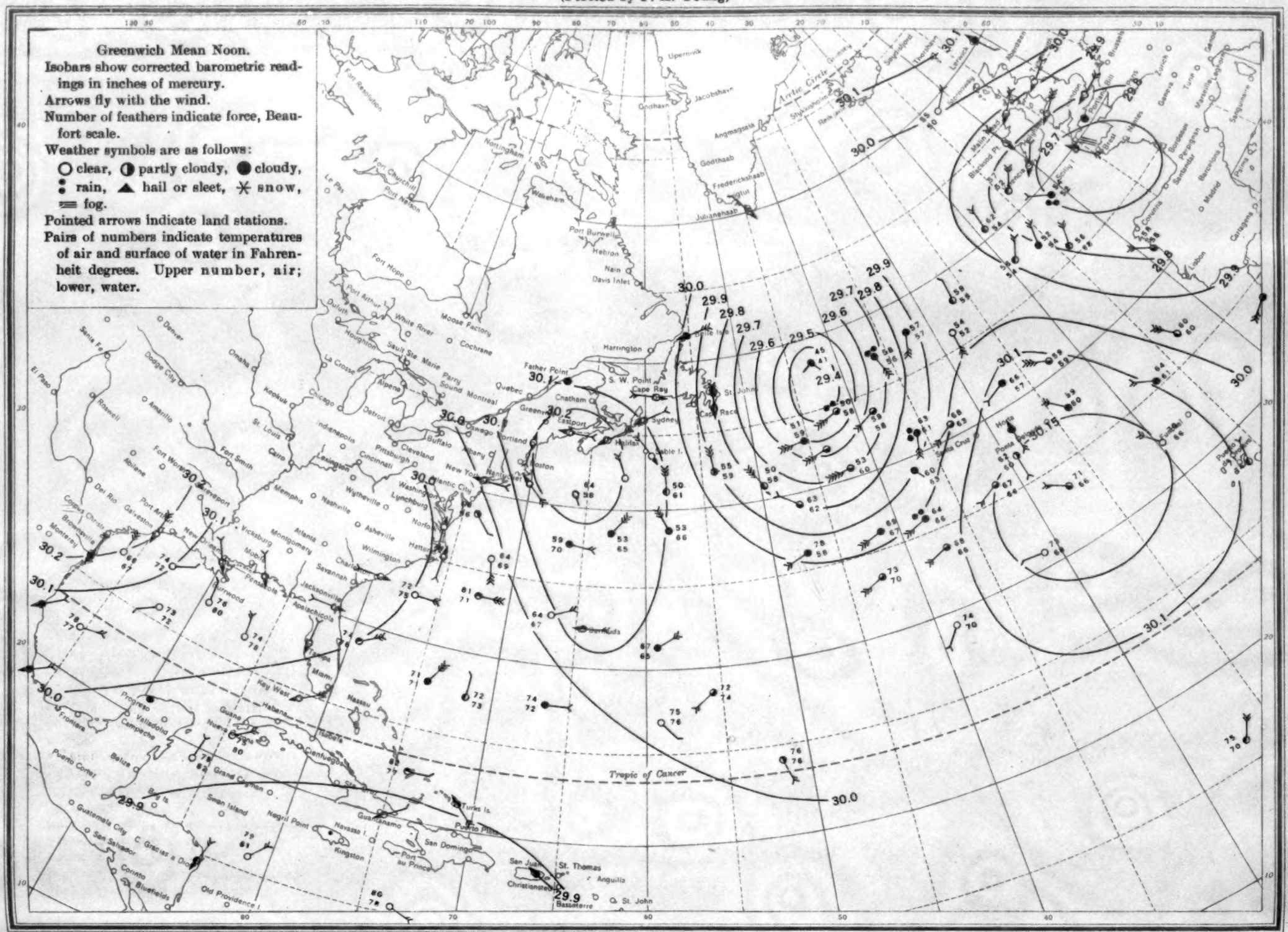

Greenwich Mean Noon.
Isobars show corrected barometric readings in inches of mercury.
Arrows fly with the wind.
Number of feathers indicate force, Beaufort scale.
Weather symbols are as follows:
clear, partly cloudy, cloudy, rain, hail or sleet, snow, fog.
Pointed arrows indicate land stations.
Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.
Arctic Circle
Tropic of Cancer
Upernivik
Godhavn
Jacobshavn
Angmagssalik
Godthaab
Fredericksh aab
Julianehaab
Port Burwell
Hebron
Nain
Davis Inlet
Fort Resolution
Nottingham I.
Wakeham
Fort Churchill
Port Nelson
Le Pas
Fort Hope
Port Arthur
Duluth
White River
Moose Factory
Cochrane
Houghton
Sault Ste. Marie
Parry Sound
Montreal
Quebec
Father Point
Harrington
S. W. Point
Cape Ray
Chatham
Eastport
Portland
Boston
Sydney
Halifax
Cape Race
St. John's
Greenwood
Buffalo
Cleveland
Detroit
Chicago
Keokuk
Omaha
La Crosse
Alpena
Albany
New York
Atlantic City
Washington
Lynchburg
Norfolk
Wytheville
Asheville
Nashville
Memphis
Cincinnati
Pittsburgh
Lexington
Indianapolis
St. Louis
Cairo
Fort Smith
Shreveport
Vicksburg
Montgomery
Atlanta
Mobile
Pensacola
Jacksonville
Apalachicola
Savannah
Charleston
Wilmington
Hatteras
Miami
Key West
Havana
Nassau
Bermuda
Turks Is.
Guantanamo
Puerto Plata
San Domingo
Port au Prince
Kingston
Navassa I.
Negril Point
Swan Island
Grand Cayman
Cienfuegos
Nuevitas
Guana
Progreso
Valladolid
Campeche
Frontera
Belize
Puerto Cortez
Guatemala City
San Salvador
C. Gracias a Dios
Bluefields
Corinto
Old Providence I.
Bird Is.
Roseau
Basseterre
St. Thomas
Anguilla
St. John
Christiansted
San Juan
Santa Cruz
Funchal
Lerwick
Stornoway
Aberdeen
Valentia
Blacksod Pt.
Galway
Belfast
Donaghadee
Holyhead
Scilly I.
Falmouth
Portland Bill
Brest
Jersey
Guernsey
Ushant
Le Havre
Cherbourg
Roches Pt.
Dublin
Skyskerries
Reikjavik
Seydisfjord
Thorshavn
Shetland
Kirkwall
Stromness
Belle Isle
Main Head
Bordeaux
Perpignan
Barcelona
Madrid
Lisbon
Coruna
Santander
Gibraltar
Malaga
Cartagena
Palma
Marseilles
Toulon
Nice
Genoa
Turin
Geneva
Lucerne
Zurich
Brussels
Ostend
Copenhagen
Skagen
Christiansund
Haparanda
Stockholm
Visby
Helsingfors
Hangoe
Libau
Windau
Memel
Pillau
Danzig
Swinemunde
Stettin
Berlin
Hamburg
Helgoland
Terschelling
Ijmuiden
Delfzijl
Den Helder
Vlissingen
Flushing
Ostende
Calais
Boulogne
Dunkirk
Havre
Paris
Nantes
Rochefort
Pauillac
Arcachon
Biarritz
Santander
Coruna
Lisbon
Sagres
Cape St. Vincent

Chart X. Weather Map of North Atlantic Ocean, May 6, 1928

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ≡ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

Chart XI. Weather Map of North Atlantic Ocean, May 7, 1928

(Plotted by F. A. Young)

Greenwich Mean Noon.

Isobars show corrected barometric readings in inches of mercury.

Arrows fly with the wind.

Number of feathers indicate force, Beaufort scale.

Weather symbols are as follows:

○ clear, ◑ partly cloudy, ● cloudy, ⁝ rain, ▲ hail or sleet, ✳ snow, ▬ fog.

Pointed arrows indicate land stations.

Pairs of numbers indicate temperatures of air and surface of water in Fahrenheit degrees. Upper number, air; lower, water.

Arctic Circle

Tropic of Cancer

LVI—66

May, 1928. M. W. R.